

The University of Adelaide



REPORT

of the

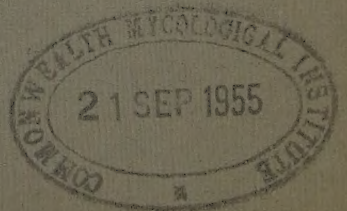
WAITE AGRICULTURAL RESEARCH
INSTITUTE

SOUTH AUSTRALIA

and associated activities of the

COMMONWEALTH SCIENTIFIC
AND INDUSTRIAL RESEARCH
ORGANIZATION

1952-1953



REPORT OF
THE WAITE AGRICULTURAL RESEARCH INSTITUTE
AND ASSOCIATED ACTIVITIES OF THE
COMMONWEALTH SCIENTIFIC AND INDUSTRIAL
RESEARCH ORGANIZATION

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CONTENTS

	Page
THE COUNCIL OF THE UNIVERSITY - - - - -	vii
THE WAITE AGRICULTURAL RESEARCH INSTITUTE	
The Staff - - - - -	ix-x
Introduction - - - - -	1
Scientific Work of the Institute - - - - -	2
Agronomy - - - - -	4
Genetics and Plant Breeding - - - - -	13
Agricultural Chemistry - - - - -	15
Plant Physiology - - - - -	19
Entomology - - - - -	20
Plant Pathology - - - - -	25
Climatology - - - - -	31
Meteorological Records - - - - -	32
Publications of the Staff, 1952-1953 - - - - -	38
Records of Field Experimental Work - - - - -	41
COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION	
Division of Soils	
The Staff - - - - -	54
Introduction - - - - -	56
Soil Survey and Pedology - - - - -	56
Soil Chemistry - - - - -	58
Soil Physics, Mechanics and Mineralogy - - - - -	61
Soil Microbiology - - - - -	65
Publications of the Staff, 1952-1953 - - - - -	67
Oenological Research - - - - -	69

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Technical Assistant : R. M. FEUERHEERDT.

MEMBERS OF THE STAFF WHO WERE ABSENT ON STUDY LEAVE DURING 1952 OR 1953 :

J. A. PRESCOTT, C. S. PIPER, T. O. BROWNING, G. M. E. MAYO.

TEMPORARY AND VOLUNTARY WORKERS DURING 1952 AND 1953 :

J. S. KANWAR (Agric. Chem.), A. S. ATWAL (Ent.), R. G. ORAM (Genetics),
J. L. DAVIDSON (Agron.), W. HARAHAP (Ent.), A. W. SIMONS (Agric.
Chem.), HARRIET B. CREIGHTON (Genetics), H. L. PENMAN (Climato-
logy), E. R. GRAHAM (Agric. Chem.).

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JANUARY, 1952 :

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The Waite Agricultural Research Institute

1. INTRODUCTION

The foundation of the Waite Institute was made possible as a result of the gift of Peter Waite to the University of Adelaide of land and property at Glen Osmond, together with an endowment.

The land comprises the Netherby Estate (112 acres) and Claremont (53 acres) adjoining the main estate of Urrbrae, making a total of 299 acres as the original gift to the University for the Institute, in addition to 114 acres to the South Australian Government for an Agricultural High School. The University has since purchased 80 acres of the Springfield estate adjacent to Netherby and 10 acres of Alverstoke for the purposes of the Institute.

Including investments to the value of £58,450, the total value of the gift was estimated at £100,000; the annual Government subsidy of five per cent amounted to £5,000, and work began with an income of about £8,000.

The first appointments to the staff were made in 1924 and 1925.

The first three laboratories were those endowed by the late Sir John Melrose, the family of the late John Darling, and the family of the late Ranson Mortlock. A fourth laboratory was completed in 1947.

In addition to the laboratories, a range of glasshouses, a cool house for biological work in the summer months, two implement sheds, a woolshed and a cereal barn have been erected since 1925.

Endowments subsequent to the original one of Peter Waite have included those of the late Mrs. Elizabeth Macmeikan, Mr. Hugh Hughes, Mr. W. D. Grigg, and Mr. W. H. Sandland. The Ranson Mortlock Trust Fund was established in 1936 by the family of the late Mr. Frederick Ranson Mortlock for research in connection with the management of pastoral lands in the more arid regions. Mr. J. T. Mortlock subsequently generously supported these investigations and on his death in 1950 made financial provision for their continuation. Mrs. J. T. Mortlock contributed a further capital sum during 1952.

Apart from its original and subsequent endowments, the Institute derives its main income from appropriations under Acts of Parliament of South Australia.

Since 1927 the Division of Biochemistry and General Nutrition of the Commonwealth Scientific and Industrial Research Organization has maintained at the Waite Institute a field station equipped with feeding pens for the nutrition of sheep under experimental conditions.

Since 1929 the Waite Institute has been the headquarters of the Division of Soils and since 1935 has housed the Oenological Research Unit of the Commonwealth Scientific and Industrial Research Organization.

For the years 1952 and 1953 under review a total sum of £12,400 was received from the Wool Research Trust Account of the Commonwealth for research into problems associated with sheep pastures, including the survey and establishment of pastures and the control of weeds and insect pests. A sum of £1,000 was received from the Aitken Pastoral Trust for investigations on onion weed.

Under the original deed of gift it was provided that portion of the estate containing an area of 67 acres should be held in perpetuity as a public park.

Effect has been given to this provision by the establishment of the Waite Arboretum, in which trees can be grown to demonstrate their value for shelter and ornament, and their adaptability to the local soil and climate. The Arboretum now has 1,150 trees, including varieties belonging to 554 different species. The first plantings were made in 1928.

The library of the Waite Institute is designed to meet the needs of a research staff, and the policy is to make it as complete a reference library as possible on matters relating to agricultural science and its related scientific disciplines. The present total of books is 3,600, and of bound periodicals, 5,700, with an additional 43,400 serials and pamphlets.

The University Department of Genetics was maintained at the Institute during the period under review but provision was made for its transfer to the Faculty of Science during 1954. Arrangements have been made for the continuation of work in Agricultural Genetics and Plant Breeding at the Institute.

Professor H. C. Trumble, who had been head of the Department of Agronomy since 1938, resigned in April, 1953.

During the two years under review, experimental work has been conducted at country centres with the goodwill and co-operation of a number of individuals and organizations. It is a pleasure to record such assistance from the following: Messrs. F. Coleman & Sons, Saddleworth; The Yudnapinna Pastoral Company; Mr. Peter Nicholls, Avon; Woods and Forests Department, Mount Burr; Mr. E. A. Wirth, Delamere; Mr. A. Smythe, Salters Springs; Mr. G. T. Pitt, Wrattontullie; Mr. J. C. King, Mount Schank; Mr. Hiram Jenkins, Mangalo; Mr. K. Filmer, Corny Point; Mr. D. G. Quinn, Viticultural Research Station, Rutherglen, Victoria; Mr. A. W. Allen, Manager, Viticultural Nursery, Wahgunyah, Victoria.

2. SCIENTIFIC WORK OF THE INSTITUTE.

The scientific work of the Institute is centred round the study of the principles of crop and pasture husbandry and of the scientific disciplines which may be associated with this aspect of agriculture. Animal husbandry is not a feature of the activities of the Institute except in so far as it is necessary for the study of pastures. The main subjects of investigation may be included in the following groups:

Agronomy and Agrostology.

The investigation of the factors affecting the production of farm crops and the improvement, establishment and management of pastures under the wide range of rainfall conditions prevailing in South Australia, the identification and control of weeds.

Genetics and Plant Breeding.

The investigation of the principles of inheritance in plants and their application in the improvement of agricultural and horticultural crops.

Plant Physiology.

The investigation of factors concerned in the growth reactions of crop plants, with particular emphasis on their water relations, and on the mechanism of elongation.

Plant Pathology.

The investigation of the diseases of agricultural and horticultural crops and of forest trees.

Entomology.

The investigation of the insect pests of agricultural and horticultural crops, of stored products and of forest trees.

Agricultural Chemistry.

The classification of soils; the investigation of soil fertility problems; the chemical study of plant viruses; the chemical study of pastures.

The Waite Institute, in addition to its principal function of research, provides scientific advisory services in systematic botany, plant pathology and entomology to the Minister responsible for the State Departments of Agriculture and of Woods and Forests. The University of Adelaide maintains a School of Agricultural Science and in conjunction with the Roseworthy Agricultural College provides courses of instruction leading to the degree of B.Ag.Sc. Of these courses, those in the second and third year in agriculture, genetics, agricultural chemistry, mycology, plant pathology and entomology are provided at the Waite Institute.

Increasing use is being made of the facilities provided in the several departments for post-graduate training leading to the higher degrees.

The Work of the Institute

Agronomy

The problem of land use in South Australia does not differ basically from that of other regions, namely the development of systems which will ensure maximum pastoral and agricultural productivity on a permanent basis. Much of the better rainfall area of the State has soils of low natural fertility and in these regions the first need is to effect a substantial improvement in fertility status. This is being achieved over considerable areas through research and practice in improved plant nutrition and by the selection and development of adapted species and varieties of pasture plants, especially herbage legumes. Since 1925 the Institute has engaged in a considerable programme of research in this sphere, and work on both species and nutrition problems continues as an important phase of the Institute's programme.

On the more fertile soils, such as the red brown earths of the Adelaide plains, there is clear evidence of decline of production under narrow crop rotations, a decline associated with deterioration both of structure and nitrogen status. A number of field rotation studies are in progress at the Institute to determine the influence of various crops and practices on fertility trends and the manner in which such influences are exercised. A newly developed phase of such studies is the relationship of crop and pasture practice to soil aeration.

Work has commenced in the field of crop physiology. Studies are being made of the relationship of the growth of subterranean clover to various environmental factors.

1. PERMANENT ROTATION EXPERIMENT (C1).

This experiment, which was commenced in 1925, includes comparison of ten systems of crop rotations in which the principal crop is wheat. A permanent plot of sown pasture is maintained also in the experiment.

The mean yields for the period 1925-53 (both grain and total produce) together with the yields of the 1952 and 1953 seasons are given in Tables 1 and 2 on pages 41 and 42. The number of years of record on which long-term means are based differs from that used in previous reports. The first year of record in each case is taken as the first season's crop after a full cycle pretreatment. Several of the rotations, particularly those involving leys of up to 4 years, have been in progress only since 1949 and the full cumulative effect of such rotations will be determined only after several further cycles. There is, nevertheless, clear evidence that these longer term rotations are leading to appreciable increases in crop yield.

The magnitude of the yield differences between narrow and broader rotations was particularly striking in 1953. Conditions at and just after seeding were extremely wet and this may have been a factor giving a wider range of relative yields than has been usual. The following table compares wheat yields in the season of 1953 in rotations of length from one to four courses which have been maintained for not less than 26 years:

Rotation.								Bushels per acre.
Wheat, continuously	-	-	-	-	-	-	-	0.6
Wheat, bare fallow	-	-	-	-	-	-	-	9.6
Wheat, peas	-	-	-	-	-	-	-	11.7
Wheat, oats, fallow	-	-	-	-	-	-	-	17.1
Wheat, pasture, fallow	-	-	-	-	-	-	-	12.6
Wheat, oats, pasture, fallow	-	-	-	-	-	-	-	31.8

2. INVESTIGATIONS ON FORAGE CROPS AND TEMPORARY PASTURE IN FOUR-COURSE ROTATIONS WITH WHEAT. (C 53).

The following rotations are on trial to compare the effects of various forage crops and pasture treatments on soil fertility, using wheat as the reference crop:

1	2	3	4	5
Fallow	Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat	Wheat
Fallow	Oats	Oats*	Peas	Peas
Wheat	Pasture	Pasture	Pasture	Grazing Oats

* With added ammonium sulphate.

The pasture phase in rotations 2, 3 and 4 is Wimmera rye-grass and in 5, grazing oats. Superphosphate is applied to all crops and pastures. Half of each plot sown to forage is harvested each year and the other half-plot is grazed by sheep.

Changes were made in the original layout of rotations and the results presented in Table 4 give firstly, means based on the period to 1948, which are comparable only for rotations 1, 2 and 4, and secondly means from 1949 onwards which are comparable for all treatments. The results of the seasons of 1952 and 1953 are given in Tables 3 and 5 and an analysis of the results 1949-53 in Table 6.

Mean yields have been calculated on data collected only from plots which have had a full cycle pre-treatment.

The Wimmera ryegrass pastures in 1953 were very poor, yielding only 6.0, 6.6 and 10.3 cwt. per acre, the latter occurring after peas. In contrast, the pasture of grazing oats yielded 25.6 cwt. of dry matter per acre. The pastures were sown later than usual and conditions at seeding and throughout the first half of the growing season were extremely wet. Determinations of total nitrogen towards the end of the growing season showed almost equally poor nitrogen status in pasture after either peas or oats. It seems probable that there was rapid leaching of nitrate nitrogen during the wet winter before rising temperatures permitted vigorous pasture growth to exploit the soil nitrogen supply.

A further point illustrated by the 1952 and 1953 results is the varying magnitude of the difference between the yields of the crop phases of the rotations according to whether the previous forage crops (oats or peas) had been grazed or harvested.

Yield of dry matter cwt. per acre.

Rotation	Crop	1952 (probably ideal season)		1953 (very wet season)	
		Forage grazed	Forage harvested	Forage grazed	Forage harvested
2. Wheat, oats, pasture, fallow	Wheat	55.1	43.1	33.9	33.3
	Oats	20.6	10.0	2.3	2.5
4. Wheat, peas, pasture, fallow	Wheat	73.1	55.2	40.7	33.6
	Peas	36.9	34.8	22.7	8.4

It seems that in such excessively wet seasons as 1953 growth may be limited by either:

- (a) "direct" effects of water-logging, e.g. adverse conditions for germination or poor aeration of roots;
- (b) "indirect" effects such as leaching of soluble nitrogen or a deterioration of soil structure leading to decreased permeability, and hence reduced effectiveness of rainfall later in the growing season.

The interaction of rotation and season (rotation 2 showed no advantage in the wet year, of grazing the previous forage crop; rotation 4 showed an advantage in both seasons) suggests that nitrogen may be the factor involved. Rotation 2, which included an oat crop as well as the wheat crop and would thus be more depletive of nitrogen supply, would be more affected by the leaching of nitrogen in a wet year than the rotation 4 which was less exploitive of nitrogen.

The inclusion of peas in the rotation as compared with oats has given a substantial increase in the yield of wheat. Thus during the years 1949-53, the values were as follow:

With peas in rotation bush/wheat	With oats in rotation bush/wheat
40.9	31.7

The application of sulphate of ammonia to the oats in rotation 3, as compared with rotation 2, has given a very substantial increase in the oat production. Further, where the oats were grazed, and to a much lesser degree where they were harvested, there has been a consistent benefit in the wheat yields three years later. The following figures show the mean wheat yields for 1949-53:

	Oats in rotation bush/wheat	Oats with sulphate of ammonia in rotation bush/wheat
Oats grazed - - - -	33.2	37.4
Oats harvested - - - -	30.3	31.9

Some caution is still necessary in interpreting these results as the oats with nitrogen replace the barley of the early years of the rotation and there is evidence of eel-worm infestation in the oat crops, which infestation appears to be related to the number of oat crops previously grown.

3. INFLUENCE OF PASTURES AND FORAGE CROPS ON THE YIELD OF WHEAT IN ROTATIONS OF VARYING DURATION (C92).

The rotations on trial are:

- (a) Fallow-Wheat.
- (b) Peas-Wheat.
- (c) Two Years Pasture-Fallow-Wheat.
- (d) Three Years Pasture-Wheat.
- (e) Six Years Pasture-Wheat-Wheat.

A detailed summary of the experiment has been given in the previous report. Due to limitation of space when the experiment was laid out, a series of only three blocks, to be commenced in successive years, was possible. The first set of data for all rotations will be available on the first block at the end of the 1954 season. Tables 7 and 9 give the results of the 1952 and 1953 harvests and Table 8 gives an analysis of the two and four course rotation data.

The higher yields of wheat in 1952 (Table 7, p. 48) correspond to favourable conditions at seeding whereas, as mentioned previously, the season was extremely wet in 1953 with correspondingly lower yields.

The low yield of wheat after six years of pasture appeared to be in part due to take-all. This disease has been associated with the high proportion of barley-grass in the preceding pasture phase. By the third or fourth year of the pasture phase, barley-grass became dominant under the grazing management found practicable on small plots. Another factor contributing to this low yield (14.4 bushels per acre) was the difficulty of seed bed preparation following six years of *Phalaris* pasture. This was aggravated in 1953 by adverse weather during the autumn.

Determination of the influence of physical and chemical characters of the soil on the nutrient status of the plants is as yet inadequate to assess fully the merits of the treatments. However, it appears that leys of only 2-3 years may effect a substantial amelioration of soil structure. On plots at the Waite Institute which have been previously subjected to a long period (ca. 20 years) of a wheat-fallow rotation, soil structure improvement to a state similar to that of nearby virgin grassland was accomplished in 2-3 years. (These determinations were made by the Soil Physics Section of C.S.I.R.O.). However, the rate of deterioration subsequent to rejuvenation by pastures, and hence the number of croppings possible after a ley, needs further investigation.

4. TOP-DRESSING OF NATURAL PASTURE (P1).

The permanent field experiment which was commenced in 1925 to follow the effects of different forms of added phosphate on the yield, botanical composition and carrying capacity of natural pasture is being maintained.

Phosphorus, at the rate of 40 lb. P_2O_5 per acre per annum, is added as basic slag, ground rock phosphate or superphosphate. A plot receiving sodium nitrate at 78 lb. per acre plus superphosphate is also included.

The trend mentioned in the previous report is continuing, i.e. the maintenance of higher yields of dry matter on the rock phosphate than on the superphosphate plot after the first 8-10 years of treatment, viz.:

<i>Yield of herbage (cwt. dry matter per acre),</i>						
				Superphosphate Plot	Rock Phosphate Plot	
1952	-	-	-	-	71.8	84.8
1953	-	-	-	-	58.3	62.6

The results of the experiment for 1952 and 1953 are given in Tables 10 and 11 while the mean results to date are given in Table 10. Opportunity has been taken of checking and correcting the full grazing records, in terms of sheep days, relating to this experiment. These estimates for each year of the full period since 1928 are given in Table 12.

5. PASTURE INVESTIGATIONS ON VIRGIN IRONSTONE SOIL.

Following initial field work in 1951 by the Soil Microbiology Section, C.S.I.R.O., with subterranean clover on a virgin ironstone soil near Delamere, S. Aust., the Department of Agronomy undertook the nutritional aspects of the investigations in this area. The application of relatively heavy rates of phosphate in a suitable form is essential for successful clover establishment on this soil. Complete failure occurred without superphosphate, while ground rock phosphate was valueless as a source of phosphorus over the two years that the experiment has been conducted. The major part of the work has been directed to an elucidation of the cause of increased yield of clover following the application of calcium compounds in the presence of superphosphate and trace elements. This increased yield is associated with an increase in the number of large healthy plants and a decline in the number of poor plants. In the first year, there was no effect of lime in the absence of superphosphate, while the increase in yield was particularly marked at the highest rate of superphosphate used (12 cwt per acre). Slaked lime, gypsum and limestone fines (CaCO_3) all gave an increase in yield, slaked lime being the most effective, while limestone fines were the least effective.

In the second year in the field increased yields with calcium compounds were secured only at low rates of superphosphate (3 cwt. per acre or less); at higher rates (6–12 cwt. super per acre) gypsum had no effect and slaked lime and limestone fines caused a depression in the yield of clover.

In glasshouse experiments with subterranean and white clovers in Delamere soil it was shown that to be effective in increasing clover yield the calcium compound must be applied in the same soil layer as the phosphate and trace elements. The application of potassium, magnesium, iron, boron, cobalt, vanadium and additional copper, zinc, manganese, molybdenum and sulphur did not influence the effect of the calcium compound.

Chemical analysis of field and glasshouse plant material indicates that the nitrogen content of the plant material as well as its calcium content may be influenced by the application of calcium compounds, especially slaked lime.

Further investigations on the interaction of calcium with phosphate and other nutrients are being carried out in an attempt to define the factors concerned in the influence of calcium compounds on the growth of clovers on this soil.

6. STUDIES WITH PASTURE SPECIES.

The studies on *Medicago tribuloides* (Barrel Medic) briefly reported in 1950–51 have been continued. Further collections of seed from two country centres have been examined. Twelve samples from the Auburn-Balaklava district and seventeen samples from the Christies Beach-Morphett Vale district were grown as spaced plants, and observations were made on the morphology and time of flowering of sixty plants in each sample. The extremes of weather (wettest July and driest September) during the growing period somewhat affected the uniformity of the trial.

The northern group (Auburn) was in general later flowering and more variable than the southern (Christies Beach) group. It was not possible to correlate at all precisely the variability between the samples with their original environment.

Crosses have been made between seven variants of Barrel Medic. In nearly all crosses there was considerable expression of hybrid vigor in the F_1 and only two of forty-two combinations gave seed yields below that of the higher yielding parent. In no case was the yield below that of the lower yielding parent. Male sterility and the direction of pod coiling are simply inherited. The presence of spines on the pod is also simply inherited but a number of genes determine the particular nature of the spines. Complementary genes determining the production of albino seedlings were revealed in one line (C.S.I.R.O. *Mtrb* 173) with respect to the other six variants of the species. While the presence of anthocyanin is simply inherited, the control of its pattern in the leaf appears complex. In crosses between early and late flowering strains some F_2 lines are earlier than the first flowering parent.

Phalaris Species. A collection of *Phalaris* plants has been assembled and inbred lines will be developed to see whether it is possible to exploit any hybrid vigour in this long lived pasture plant. They cover a range of morphological types and considerable differences in self fertility were revealed on the first selfing.

The nutritional disorder of sheep "Phalaris Staggers" is associated with the animal's uptake of cobalt when grazing on pastures of *Phalaris tuberosa*. As a contribution to the understanding of this disease the cobalt content of individual *Phalaris* plants was investigated with the co-operation of C.S.I.R.O. The following table shows the values of cobalt (ppm of oven dried material) from the tops of individual plants grown in the field in 1952:

Cobalt content, ppm dry weight, of individual Phalaris plants.*

						Mean
<i>Ph. coerulescens</i>	- - -	·052	·079	·098	·062	·073
<i>Ph. truncata</i>	- - - - -	·041	·025	·27	·15	·121
<i>Ph. tuberosa</i>	-					
1. From Turkey	- - -	·15(A)	·21	·14(B)	·13	·16
2. From Morocco	- -	·10	·10	·084	·11	·10
3. From California	-	·092	·050	·067	·056(C)	·067
4. From Pretoria	- -	·082(D)	·097			·089
5. From local seed	- - -	·084	·12			·10

The cobalt values suggested that considerable differences in cobalt content were to be found in plants of different genotype and that this might offer a contributory means of preventing Phalaris staggers. In 1953 single tillers of four *Phalaris tuberosa* plants (indicated as A B C and D in the above table) were used to establish plants in large earthenware pots of Urrbrae loam, which contains 13 p.p.m. of cobalt. Five seedling plants from selfed heads of each of the above four parent plants were included in the same experiment. The Phalaris tops were cut at a slightly earlier stage than in the first trial. In neither the replicate clones nor in the progenies was any significant difference in content established between the four plants, nor were progeny means related to clonal means. The cobalt values were of a lower order than in 1952 (mean of 4 plants

* Analyses (spectro-chemical) by D. J. David.

·107 p.p.m. in 1952 and ·042 in 1953) and it is thought that the limited volume of soil exploited by the roots in pots in 1953 as compared with field-grown plants in 1952, may have reduced the expression of any inherent differences.

7. THE CONTROL OF *Asphodelus fistulosus* (ONION WEED) BY COMPETING PASTURE PLANTS.

Field experiments at the Waite Institute and at Avon, in a mallee environment, have continued during 1953 and 1954. In each instance 5 pasture mixtures or species (including volunteer pasture) at 5 levels of nitrogen supply have been studied in relation to the density and growth of the onion weed. Striking differences in onion weed population have developed. Where a vigorous growth of a perennial species, either grass or legume, has occurred, there has almost been an elimination of onion weed; where the perennial species was weak (e.g. perennial ryegrass at the Waite Institute) only partial control was achieved. Annual species such as Wimmera ryegrass or volunteer annuals have been ineffective in the control of onion weed.

At the commencement of the third season of the experiment at Avon, lucerne had reduced the population of perennating onion weed plants to 400 per acre, compared with 28,600 per acre in plots carrying volunteer pastures of annuals. Similarly, the number of seedlings was reduced from 3·6 million to 0·6 million per acre, respectively. Perennial veldt grass (*Ehrharta calycina*) was less effective as a weed controlling species with values of 10,200 perennating plants and 2·3 million seedlings per acre.

At the Waite Institute *Phalaris tuberosa* was the effective competitor in onion weed suppression. While volunteer annual pasture carried 29,200 perennating plants and 9·0 million seedlings per acre, pasture of *Phalaris* had reduced these values to 1,200 plants and 0·9 million seedlings.

At each centre the annual Wimmera ryegrass proved an ineffective competitor, though it reduced the population of plants and seedlings by up to 30 per cent. While the effectiveness of strongly growing perennial species in suppressing onion weed was high at all levels of nitrogen supply, the influence of nitrogen supply on less effective species was most marked. For example, at increasing levels of nitrogen supply, perennial ryegrass (a marginal species at the Waite Institute) progressively reduced the onion weed population from 20,400 to 16,200; 15,400; 7,600 and 3,000 plants per acre. Even such a relatively weak competitor as Wimmera ryegrass showed reduction of onion weed from 29,200 to 12,600 plants per acre as nitrogen level was increased.

8. INVESTIGATIONS IN CROP PHYSIOLOGY.

(a) In 1952 a series of investigations was commenced to establish quantitative relationships between the growth of subterranean clover (*Trifolium subterraneum* L.) and certain factors of the environment. The first experiment determined the effects of total amount of light, mean maximum temperature and mean minimum temperature on the growth rate of the variety Bacchus Marsh, in the early vegetative phase. Fifty-two consecutive weekly determinations of growth rate of plants at a standard morphological stage were made, and the relevant climatic data were collected for each weekly period. Analysis of the data showed significant positive effects of light and maximum temperature, and a significant negative effect of minimum temperature on net assimilation rate.

There was a significant negative effect of light, and a significant positive effect of temperature on leaf-area ratio. Relative growth rate is the product of net assimilation rate and leaf-area ratio and proved to be independent of temperature, but significantly correlated with the amount of light received.

The second investigation was concerned with the effect of increasing plant numbers, and thus the interplant competition, on the growth of the same variety of clover. It was shown that maximum dry matter produced per unit area was achieved at relatively low plant numbers and maintained at higher densities. The effects of increasing density on individual plant development were analogous with those of artificially imposed shading, and it was concluded that competition for light was probably the principal factor determining dry matter production under conditions of high plant numbers. A marked and rapid decline in plant numbers during the growing season was noted in the highest densities of sowing.

(b) Apparatus for the examination of soil atmosphere was designed, constructed and calibrated for use during the season of 1954. It is intended to determine the relationships between structural character of the soil, oxygen content and diffusion rate, and plant growth. All measurements of oxygen content of the soil atmosphere and of diffusion rates have been made with the use of a Pauling type oxygen analyser. The gas samples were obtained from sampling tubes after a lapse of 24–28 hours for the establishment of equilibrium by diffusion between the air of the sampler and the soil atmosphere. Measurements of diffusion rates have been made by placing nitrogen-filled chambers in the soil and allowing oxygen from the soil atmosphere to diffuse in through a moveable port. Results to date indicate that a satisfactory relationship between water-free porosity and oxygen diffusion will be established.

A survey of the range of variability of soil aeration and the factors controlling it, will form a basis for the study of the effect of adverse soil aeration on plant growth.

9. INVESTIGATION OF SHRUB PASTURES UNDER LOW RAINFALL.

The grazing trial, begun at Yudnapinna Station some 250 miles north-west of Adelaide in 1940, has been concluded, but four of the paddocks which have been grazed since 1940 at the rate of nil, 24, 48 and 72 sheep per square mile are being maintained with these rates of stocking. The results of this experiment are now being analysed.

Methods of surveying vegetation in the semi-arid areas were examined and a technique of transect survey suitable to the shrub steppe has been developed. The distributions of the perennial tree and shrub species in the experimental area (3½ square miles) was determined in detail and the general pattern of vegetation thus obtained was mapped. This investigation showed that, despite a history of 12 years of differential grazing treatments, the influences of prevailing winds, old fence lines and proximity to a dam were still very marked in their effects on vegetative cover.

During the investigations of the grazing experiment nitrogen determinations were made on the foliage of *Kochia sedifolia* (Bluebush). Together with transect studies, these indicated that the camping of sheep may result in better regeneration of vegetation providing that the intensity of stocking is not so heavy as to cause destruction of plants through trampling. At Yudnapinna during 9 months of the year, the prevailing winds are from the South to S.-E.,

so that sheep graze towards the south end of paddocks and droppings are concentrated towards the southerly boundaries. The ecological survey showed that in these parts, regeneration was better and the foliage of *Kochia sedifolia* is denser. It is of interest that despite the low and erratic rainfall (mean 8.74 inches), low nitrogen status of the soil is a further limiting factor to growth by native perennial shrubs.

Rainfall records and monthly determinations of soil moisture to a depth of 63 inches are now available for a period of 10 years, and these are being analysed to provide an understanding of the water balance in this semi-arid community. Total soluble salts and soil pH have also been included in these regular determinations.

10. SYSTEMATIC BOTANY.

The routine work in systematic botany involves the identification of plants, the maintenance of a reference herbarium, and attention to the arboretum.

In terms of the advisory service to the Departments of Agriculture and Woods and Forests, a close liaison is maintained between officers of these departments and the systematic botanist. During the years 1952 and 1953, 255 reports involving a total of 980 species were made, concerning weeds, poison plants, trees and collections of native plants.

The weeds most frequently reported on were *Cyperus rotundus* (nut grass), *Cardaria draba* (Hoary Cress), *Centaurea repens* (Russian Knapweed), *Ranunculus muricatus* (the sharp buttercup), *Cenchrus tribuloides* (Innocent weed) and various species of *Solanum* and *Asclepias* (Cotton bushes).

During this period four new weeds have been recorded in South Australia. *Elymus caput-medusae* (the medusa-headed wild rye), a native of California and a potentially bad weed was found to be well established at Black Springs near Burra. *Amaranthus deflexus*, a perennial native to Europe, was recorded from Campbelltown. *Erigeron canadensis* (Canadian fleabane) an annual native to America was discovered in the Adelaide Hills. *Solanum villosum* (Woolly night shade) native to Europe and Asia Minor, and similar in habit and general appearance to *S. nigrum* (Black nightshade) has been found at Paradise.

Records of new localities have been reported in the following cases: *Schismus arabicus* (Yudnapinna Station), *Eragrostis robusta* (Mount Compass and Cut Hill), *Oxalis compressa* (Eyre Peninsula), and *Linum strictum* (Adelaide Hills). Another interesting record is the rediscovery after 60 years of the native shrub *Eriostemon obovalis* (Bendigo waxflower) at Black Springs.

The value of the herbarium, which now contains over 8,000 mounted specimens, has been greatly enhanced by the gift of the herbarium of the late Albert Morris of Broken Hill. The work of checking and remounting this collection is in hand.

Many inquiries for seed of trees suitable for windbreaks, farms and ornamental purposes were received and where possible seed was supplied from the Arboretum.

11. COMPARATIVE YIELDS OF WHEAT, SAFFLOWER AND LINSEED.

The study of the possible introduction of oil crops to South Australian agriculture has been in progress for some years and more recently has been intensified in co-operation with the Division of Plant Industry of C.S.I.R.O.

Of special interest in this co-operation has been the investigation of Safflower, the breeding and genetics of which are dealt with elsewhere in this report.

Safflower, *Carthamus tinctorius* L. presents special agronomic problems as compared with wheat and although good yields can be obtained at the Waite Institute under ideal conditions, it is much more susceptible than wheat to hazards during germination and in the seedling stages. Several examples of poor emergence, weed competition and susceptibility to slugs have been encountered at the Waite Institute. When once established it has proved itself to be reasonably drought resistant, and although harvested as late as January has usually given a satisfactory yield dependent, in the main, on the success or otherwise of the initial establishment.

Studies are being undertaken on the conditions affecting germination and emergence in the field and on methods of controlling weeds. In addition the photoperiodic requirements of safflower are being studied.

In order to assess the relative productiveness of safflower and a standard crop such as wheat, replicated crop trials have been carried out in 1952 and 1953 with a further comparison of linseed as an alternative oil crop. The results of these trials are recorded in Table 14.

Genetics and Plant Breeding

1. WHEAT.

South Australian statistics for the 1952-53 season reveal a further increase in acreage for varieties developed by the Institute. Prominent among these varieties have been Dirk 48 and Insignia 49. Further evidence has been secured supporting the view that the medium strong variety Javelin 48 should be recommended in place of the poor quality variety Bencubbin in those areas where the latter variety has been grown for so long.

Yield trials were conducted at Saddleworth in 1952 (see Table 13, page 52) and again the crossbred Gabo $\times$ 3 Dirk (726) proved superior to Dirk 48. This crossbred has been so consistent in its performances in yield trials over the years that its naming and release now appears to be warranted.

A limited number of the more promising crossbreds were made available to the Department of Agriculture for trial at Turretfield and Minnipa.

Four new bunt-resistant crossbreds compared favourably with their susceptible prototypes. The resistance, originating in the first place from the tetraploid wheat Doubbi, was shown to be effective against all Australian races of *Tilletia caries* and *T. foetida* and to be dependent on a recessive gene.

The Institute co-operated with several overseas institutions in carrying out tests for disease resistance with the extensive world wheat collection of the United States Department of Agriculture. Valuable new sources of resistance to stem rust were detected, although genetic studies have shown that several sources previously thought as being distinct now appear not to be so.

The incorporation of the gene in Kenya C6041 for resistance to leaf rust (*Puccinia triticina*) into ten leading South Australian wheat varieties was completed in 1952, five successive backcrosses having been carried out.

2. BARLEY.

New strains of Research and Prior barley referred to in the previous report have been further tested by the Department of Agriculture.

3. FLAX.

A rust-resistant derivative of Norfolk Earl has been named Ventnor and seed stocks were made available to the Commonwealth Flax Production Committee. Trials conducted by the Committee in Victoria have been most encouraging and the new variety has given good yields of straw with fibre of superior quality. It is expected that approximately 1,200 acres will be sown with Ventnor flax at Drouin and Myrtleford in Victoria and at Mt. Gambier during 1954.

The inheritance of resistance to two Australian stocks of *Melampsora lini* in flax was further studied, and extended to include a survey of the genetic relations of simply inherited markers to genes conferring host resistances. Twenty-two host genes have been identified, seventeen conferring immunity or some degree of resistance to one or both of the stocks of rust, and five being concerned with easily scored morphological markers. The seventeen genes is the maximum number present in the varieties studied and are situated at not less than four, nor more than eight loci, according to segregation tests. Improved techniques of pollination, inoculation, analysis of control of environment have been developed to facilitate gene identification and gene property studies.

4. LINSEED.

The variety of linseed grown commercially in Australia is Walsh. Trials have been made on the performance of different varieties and selections of linseed at the Waite Institute and elsewhere. A few varieties have shown themselves to be superior to Walsh. Selections originating from a cross of Punjab x Walsh are also showing some promise. Records of the field trials at the Waite Institute are given in Tables 14 and 15.

5. SAFFLOWER (*Carthamus tinctorius* L.).

Breeding work on Safflower is carried out under a joint project of the Division of Plant Industry of the C.S.I.R.O. and of the Waite Institute. A wide range of variability has been observed within this species in respect to seed emergence, early growth habit, degree of spininess, oil content, oil quality, yield and resistance to disease.

The mode of inheritance of some of these agronomic characters has been studied and utilized in the development of new varieties, which have been released for yield trials.

Seed stocks of a spineless selection of safflower were increased during 1952, a yield of 536 lb. being harvested from $\frac{1}{3}$ -acre. The oil content of this selection for the period 1948-1952 has ranged from 28 per cent. to 38 per cent. with a mean value of 34 per cent.

6. DANTHONIA.

Chromosome counts have been made of the native species, collected from a wide range of habitats from South Australia through to the alpine regions of New South Wales and Victoria. Altogether chromosome numbers are now known in 26 taxonomic species. Variation in stomatal size with chromosome number has been studied and the effects of environmental differences tested. *Danthonia caespitosa* has been shown to consist of at least four natural species,

distinguishable by chromosome number and by differences in leaf anatomy. This taxonomic species includes diploid (24 chromosomes), tetraploid (48) and hexaploid (72) types, which, however, show no consistency in distribution; the tetraploids are the commonest and most widespread.

7. PHALARIS.

The chromosome numbers of all species of the grass genus *Phalaris* have been counted. Cytological study of two species hybrids have thrown light on the relationship between the species and have disclosed a new kind of abnormal behaviour of univalents and a way in which new variation may arise. The breeding system of the self sterile *Ph. aquatica* has been analysed by observing pollen germination and growth on styles; the genetical analysis has disclosed an entirely new system of compatibility control which may be widespread amongst the grasses.

8. GENERAL GENETIC STUDIES.

In the mould fungus *Neurospora crassa* the inhibition of mutants requiring histidine has been investigated. Combinations of certain amino acids prevent uptake of histidine, presumably by blocking the surface mechanism responsible for uptake. This occurs also in the wild type, but because the latter is independent of histidine for growth the effect is transient. Genetical and cytological studies of the pseudo-wild types, appearing in crosses of pseudoallelic pyridoxineless mutants, have suggested they owe their origin to chromosomal aberrations. Strains differing in the presence and absence of polyphenol oxidase, and in the production of substances detectable by ultra violet fluorescence, have been studied. Competition between strains and especially the mechanism of suppression of one mutant by others in mixed culture have continued. These are of particular significance in relation to the testing of physical and chemical treatments, including fungicides, herbicides and insecticides, some of which have been supposed to have effects on mutation.

Methods for the study of nutritional mutants of a small green plant under completely controlled, aseptic conditions have been developed. Several classes of mutant have been obtained, and it is likely that the method would be useful for model experiments of many kinds. Study of the genetics of certain trisomies and nondisjunctional gametics in *Oenothera* interchanges has been completed. The residual genotype has been shown to affect non-disjunction of interchanged B-chromosomes in pollen development in maize and their preferential fertilization of eggs. The production and study of tetraploid stocks of maize is in progress.

Agricultural Chemistry

The research activities in Agricultural Chemistry fall into two main fields, the study of problems of soil fertility and the study of the chemical attributes of plant viruses. In the former field attention has been paid to the relative availability of compounds of phosphorus in South Australian soils generally and to the responses of these soils to different types of phosphatic fertilizers. Much of this work has been centred on a detailed study of the Seddon series of soils of Kangaroo Island.

1. INVESTIGATIONS OF SOILS FROM KANGAROO ISLAND.

The *Seddon* series of soils is the most important group of soils in the area of Kangaroo Island being developed by the Land Development Executive. This series is of exceptionally low initial fertility and the current studies are directed not only to the mineral deficiencies which may be encountered and corrected in the initial phases of development, but also to those which may appear in the later phases.

The deficiencies to be corrected in the initial phases are those of nitrogen, phosphorus, copper and molybdenum. Reserves of potassium have proved to be low and under some conditions reserves of available manganese can be rapidly depleted.

The rate at which the fertility of these soils can be built up is being studied by laboratory and pot experiments, and, in co-operation with the State Department of Agriculture, by field experiments.

Phosphorus: The *Seddon* soil is characterized by a Kaolinitic clay and contains free aluminium oxide as Gibbsite. Such soils are generally suspected of having marked fixing powers for phosphate and this coupled with the low amount of phosphate initially present, might be presumed to accentuate the deficiency in phosphorus.

Applications of superphosphate of up to 6 cwt. per acre were shown in previous years to give responses proportional to the amount of phosphate added and important additional responses were obtained when up to one ton of superphosphate per acre was applied. The test plant (subterranean clover) takes up a constant but low amount of phosphorus for all applications up to 6 cwt. per acre. This constant value of 0.19 per cent. of P_2O_5 in the dry matter would represent the minimum amount to be expected in healthy plants. Only when heavier dressings of phosphate were applied did the amount of phosphorus in the plants reach values more in line with those observed on normal soils. This may have a bearing on problems of animal health.

Of the superphosphate applied 11-20 per cent. was recovered in the crop in the first season on a virgin soil but the balance appeared to be readily available for use in the season following that of application. However, where the land has been under development for some years, as on the Experimental Block at Parndana, marked responses are still obtained with further small applications of superphosphate both in yield and in the uptake of phosphorus by clover. The proportion of the applied phosphorus recovered is, in fact, somewhat greater than in the case of the virgin soil. The recovery is in any case only about one-half of that recovered by clover from superphosphate applied to the *Urrbrae loam*.

Rock phosphate is of little or no value on this soil in its first year of application but the silico-phosphates again proved to be satisfactory.

Copper and Molybdenum: In other pot experiments the response to these micronutrients and their uptake by the plant has been examined. Applications of molybdenum to subterranean clover gave highly significant increases of yield at all levels of superphosphate tested. The increases were most marked at the 4 and 6 cwt. levels. Heavy applications of copper, either as the soluble sulphate (1 cwt. per acre) or equivalent amounts of a copper-saturated peat, failed to lead to big increases in the copper absorption by oats. Oats growing on soil from the Parndana Experimental Block, to which 10-12 lb. of copper sulphate

per acre had been applied several years previously, contained significantly more copper than those growing on virgin soil. However, the application of a further 112 lb. of copper sulphate per acre to the soil in pots failed to give more than a small increase (20 per cent.) in the copper content of oats. In contrast to oats, subterranean clover absorbs copper more readily. Small applications of copper sulphate markedly increase the copper content of clover and applications of up to 112 lb. per acre increased the copper content fivefold. In pots there was no depression in yield with this heavy application.

Manganese: Although manganese deficiency is not in evidence in the first year on the Seddon soil, its occurrence can be induced by liming, and the available manganese is rapidly depleted by growing two or three successive crops of subterranean clover in pots of this soil. The manganese content of plants declined markedly under these conditions and a limiting content of 25 parts of manganese per million was established for the maintenance of healthy clover. The symptoms of this deficiency have also been recognized in subterranean clover and described, and also identified in the field where the land has been roughly prepared for pasture.

Nitrogen: Pastures have been established sufficiently long on the experimental area at Parndana on Kangaroo Island to provide material for the study of the rate of accumulation of soil nitrogen from its initially low level. The method used has been the study of the amount of nitrifiable nitrogen in soil samples representative of varying stages of land development. Where clover has been carried for 12 years, the mineralizable nitrogen so measured was much higher than in the case of the adjacent virgin areas. In the more recent areas under experiment, no measurable soil changes have as yet been found. In all field samples of *Seddon* soil so far examined, amounts of ammonium-nitrogen have been found to be somewhat higher than commonly present in soils generally.

2. THE AVAILABILITY OF PHOSPHATES IN SOIL.

The field experiment to determine the residual value of superphosphate at the Waite Institute has been continued. It has now been in progress for six years and the yields of both wheat and barley in a fallow-wheat-barley rotation have been determined annually together with the amounts of phosphorus and nitrogen taken up from the soil by each crop. Of the residual phosphate present at the commencement of the experiment, approximately one-sixth has now been removed from the control plots. Yields are still being maintained at a high level although some seasonal influences affected the response in 1953.

Pot trials have been continued with silico-phosphate and for the first time it has been possible to include the original Rhenania phosphate, the proto-type of silico-phosphate. Silico-phosphate has continued to give very favourable responses on both *Seddon gravelly sandy loam* and on *Urrbrae loam*, using subterranean clover as the test plant. On the basis of yield of dry matter and amount of phosphate absorbed it has proved equal to or slightly better than equivalent amounts of superphosphate. Its residual value is being further examined. Clover growing on *Seddon* soil treated with silico-phosphate was a slightly deeper green than plants receiving superphosphate.

A series of subterranean clover samples from the Adelaide Hills and from the south-east of the State was examined in order to assess the normal variations

in P_2O_5 contents. Mean values of P_2O_5 in the dry matter for these two districts were 0.66 per cent. and 0.62 per cent. respectively.

3. MISCELLANEOUS SOIL STUDIES.

Nitrification studies have been continued and, in addition to soils from the field experiments on Kangaroo Island already mentioned, samples from other field experiments at the Waite Institute and at Delamere have been examined. In field experiment C53 at the Waite Institute there were no significant differences in the amounts of nitrifiable nitrogen in the three rotations examined. The loss of nitrite from some soils has been further examined in the laboratory, in relation to pH and soil organic matter. Lack of appreciation of this loss may at times invalidate determinations of nitrite in soils.

Post-graduate students have studied the availability of phosphorus and copper in soils and a new method for the determination of readily available phosphorus has been proposed. This is now being tested on a wide range of soils. A pot experiment has been started to determine the responses of *Pinus radiata* to different fertilizer treatments when grown on *Seddon* soil. *Seddon* soil has also been used in a pot experiment by another post-graduate student to study the nutrition of rice.

A research worker, visiting the Waite Institute under the Fulbright Foundation, completed and published his studies on the mineralogy of Australian soils in relation to their ability to supply plant nutrients. The minerals present in the silt fraction were used to characterize the soils. Of the soils examined those known to be copper deficient contained high amounts of gibbsite. The presence of gibbsite could denote more highly weathered parent material, nearly devoid of trace elements, but it could also be a complicating factor in the availability of copper, cobalt and zinc to higher plants. The ferromagnesian and ferrocyclic minerals were not found among the assemblage of heavy minerals in the soils known or suspected to be copper deficient. Molybdenum deficient soils in general were characterized by very small amounts of weatherable minerals in the heavy fraction. Phosphorus in the minerals of the silt fraction was somewhat higher in the less weathered samples but the low levels generally were thought to be associated with an originally low level of phosphorus in the parent rocks.

4. THE CHEMISTRY OF PLANT VIRUSES.

- (a) *Exchange of character-determinants between strains of the virus of Tomato Spotted Wilt (T.S.W.).*

Probably the most important outcome of the investigations in the period under review has been the demonstration that strains of a plant virus appear to exchange character-determinants while multiplying together in plant cells.

In a previous report it was recorded that tomato plants when inoculated with a mild strain of T.S.W. were protected against the effects of a severe strain. The severe strain does nevertheless infect the protected plant but does not evoke its usual symptoms nor does it kill the plant as it does when inoculated alone. It does exert an effect on growth and reduces the yield both of fruit and of total plant material.

A possible explanation of this observation and of others observed after infecting plants simultaneously with two or more strains is that an exchange

takes place of the character-determinants which are responsible for the observed symptoms, while the strains of virus are multiplying in the plants. It should therefore be possible to isolate new strains differing from the parent strains, from plants originally infected with two or more strains.

Isolates separated from the systemically invaded portions of such plants have resulted in the separation of strains of virus which differ from both parent strains but which possess some of the characters of each of the parents.

(b) *Long-range storage of T.S.W. virus.*

The normal *in vitro* life of T.S.W. is measured in hours. By freeze-drying freshly harvested infected tissues of plants of tomato and *Nicotiana glutinosa* it has proved possible to maintain the infectivity of samples for more than eight months and there is reason to believe that the infectivity can be maintained for much longer periods. Both mild and severe strains of T.S.W. have been preserved in this way.

(c) *Electron microscopy of viruses.*

The Division of Industrial Chemistry of C.S.I.R.O. has photographed under the electron microscope preparations, made in these laboratories, of the viruses of Tobacco Mosaic, and a new strain of potato X. Extracts of leaf tissues of tomato plants infected with strain A of T.S.W. were also examined along with controls. The electron micrographs of Tobacco Mosaic show a preponderance of very long rods of a diameter of 14 ± 1 milli-microns. Some of the shorter rods had lengths from 240 to 420 milli-microns. The average diameter of the rods of potato X virus was 10.6 ± 1 milli-microns and the rods varied in length from 235 milli-microns downwards. Photographs of T.S.W. show a high concentration of spherical particles of about 15 milli-microns diameter which have not yet been identified with certainty.

(d) *General observations on T.S.W. virus.*

It has been found possible to find infective virus in ripe tomato fruit, but not in the seed. The highest concentration is in the skin at the site of the annular markings.

Plants of *Nicotiana glutinosa* are not invaded systemically by many strains of T.S.W. but systemic invasion is characteristic of the milder strains of the C complex and of the strain E. The effect of light on the ability of these strains to invade *N. glutinosa* is also under investigation. It has been found that exposure to a high light intensity inhibits systemic spread of the virus.

(e) *Metabolism of virus-infected plants.*

In addition to the fluorescent benzopyrone, scopoletin, it has been found that at least two other fluorescent substances accumulate in greater amounts in virus infected plants than in healthy plants. Differences in the amounts of other non-protein substances in healthy and infected plants are also being studied.

Plant Physiology

A quantitative study of the rate of transpiration from plants has been continued. A detailed investigation of a single wheat leaf as a transpiring system has confirmed the importance of stomata in influencing the rate of water loss.

Considerable difficulty was experienced in measuring the diffusive conductance of the stomata in quantitative terms; this has recently been achieved and a full analysis of the transpiration rate in terms of diffusive conductance of the stomata, wind velocity and leaf size will be published in due course. Wind velocity has little overall effect on the transpiration rate, the increase in potential loss arising from the decreased boundary layer with higher velocities being offset by a concurrent partial closure of the stomata.

The study has been extended to the field where evaporation rates from a wheat crop have been measured by the aerodynamic method developed by Pasquill, in which the temperature and atmospheric humidity are measured with great precision at varying heights above the crop. The daily rates of evaporation which were measured were found to be lower than rates expected from the formula due to Penman. This may be attributed to the systematic under estimation of the evaporation rate during the day by the method used as well as to difficulty in accurately estimating the plane of zero turbulent exchange. Considerable scatter was experienced in estimates of this porometer under adiabatic conditions. An analysis of the measured losses in terms of meteorological and plant components is now in progress.

Certain aspects of cell elongation have also been studied. An analysis of the relationship between elongation of *Avena* coleoptile sections, concentration of indole-acetic acid, and time, showed that in optimal concentrations ($\sim 1 \times 10^{-5}M$), a linear relation exists between elongation and time for about 6 hours and is then followed by a decreased rate of elongation with time. With supra-optimal concentrations ($\sim 1 \times 10^{-3}M$), the rate of elongation is initially higher than with the optimal concentration, but the rate is maintained for only about $1\frac{1}{2}$ hours, and elongation ceases after about 3 hours. The sections then shrink to a constant extent. The respiration rate falls sharply within the first 20 minutes from exposure to the high concentrations. At these concentrations, the percentage increase in water uptake lags behind the percentage increase in length; there is actually a period before maximum elongation is reached during which sections increase in length without concurrent uptake of water. This behaviour is not due to gradients of auxin along the section nor to changes in relative dimensions of the cell. These and other experiments are interpreted as indicating that water enters the cell as a consequence of active growth of the cell wall and is presented as evidence contrary to the concept of "active water uptake" as the primary force in elongation. The behaviour is being analysed more closely with the aid of mannitol solutions of varying osmotic concentration.

Ethylene has also been used to control elongation. Experiments with excised cylinders of *Avena* coleoptiles show that ethylene increases the sensitivity of this tissue to indole-acetic acid. The exact nature of the mechanism is still speculative and is being further investigated.

Entomology

During the past two years work on pasture insects has been continued and extended; an investigation of the armyworm group of caterpillars has been commenced.

The manuscript of a textbook on animal ecology, written by Dr. H. G. Andrewartha in conjunction with Dr. L. C. Birch of the University of Sydney,

has been completed and is in the printer's hands; it is entitled "The Distribution and Abundance of Animals" and will be published by the University of Chicago Press.

1. INSECT PESTS OF PERMANENT PASTURES.

Studies were continued on the native underground grass-grub, *Oncopera fasciculata* Walk., which has been under investigation in the South-East of South Australia for some years. During 1952 and 1953 this insect continued to be scarce; it has not caused serious economic damage since the outbreak years of 1948 and 1949. Weather appeared to be of major importance in limiting its dispersal and abundance, and studies were concentrated on this aspect of its ecology. Other components of the environment had less influence upon its numbers.

There are two "critical" periods for *Oncopera*. Dry conditions during the egg and early larval stages (October to December) cause heavy mortality in these stages. The insect is more vulnerable to such effects when it occurs on free-draining soils (volcanic and terra rossa). When it occurs on low-lying soils subject to flooding (meadow podzols and rendzinas) the mature larvae and pupae may be drowned in their burrows during the winter months (May to August).

Field experiments have shown that on well-drained soils ideal conditions for *Oncopera* are provided by high, dense, pasture and abundant rain evenly spaced from October to December (when eggs and newly-hatched larvae are present). Laboratory experiments showed that the eggs are fairly resistant to dry conditions, but any moisture lost cannot be regained; on the other hand young larvae are not very resistant to dry conditions but can pick up moisture if free water (e.g. rain, dew) is available.

The larvae of *Oncopera fasciculata* will drown if submerged in water for two days; when the soils they inhabit become waterlogged, they are forced towards the soil surface by the rising water-table, and become weakened and exposed to predators.

The following hypothesis has been formulated to describe the influence of weather on the distribution and abundance of this insect in South Australia: '(1) *Population on well-drained soils*. During a year in which rainfall is normally distributed in the late spring, the larval population is restricted to habitats which are relatively low-lying and moist. In a dry spring, localization of larval habitats is carried still further. A wet spring with rainfall extending into early summer, enables the insect to colonize and survive over a wider range of habitats; a succession of wet springs of this kind would permit widespread occurrence of the kind encountered in plague years. (2) *Population on soils subject to flooding*. During a year of average rainfall in late winter the larval population would be restricted to local habitats higher than the general level of the soil water-table. An extended wet winter would restrict the insect to the highest levels; conversely, dry conditions in late winter would favour a high survival rate on these soils by removing the risk of flooding. A series of relatively dry winters would thus favour an increased population on heavy soils.

The 1948-50 outbreak may be explained in terms of this hypothesis. Surveys made each year since 1950 show that the fluctuation in numbers, and distribution of *Oncopera* followed closely the pattern indicated. Evidence was

obtained in the spring of 1953 that a higher degree of larval survival might be expected in 1954, and if an upward trend is maintained, the population would be likely to reach economic proportions in 1955.

Work upon the pasture cockchafer (*Aphodius howitti* Hope) has been continued with the support of a grant from the Commonwealth Wool Funds. Recent investigations of the Victorian and Tasmanian Departments of Agriculture have shown that this insect may be controlled by insecticides (notably by lindane). The present investigation is intended to secure more information upon the capacity of the larvae to survive in the field when subjected to a range of conditions of soil moisture and food supply. It is hoped that this information will throw light on the factors that render pastures subject to attack by this insect, and that it will indicate aspects of pasture management that may minimize damage without requiring the use of insecticides.

During the past two years populations have been generally low throughout the State. An upward trend has been discernible during the past year, with the possibility that large numbers might be reached in 1955 if weather conditions favour it. As more land previously used for cropping is applied to continuous grazing, reports are being received of *Aphodius* in districts where it had not previously come under notice.

The work on the black field cricket *Acheta (Gryllulus) commodus* Walker was completed during the period under review. Further investigations were undertaken on the physiology of diapause in the eggs; these showed that the influence of treating the eggs for a period at a particular low temperature on their ability to continue development and hatch promptly, when incubated at some temperature within their developmental range, depended on the particular temperature at which the eggs developed. If the eggs were incubated at a rather low temperature (21° C.), more eggs developed promptly when they had been stored at 16° C. than when they were stored at either 13, 10 or 8.5° C. But if the eggs were incubated at 30° C. there was little difference between those stored at 16, 13 or 10° C., while significantly fewer of those stored at 8.5° C. developed promptly.

In a study of the capacity of the eggs to retain water under dry conditions, it was found that the eggs dried out and died in from 2 to 10 days when exposed to air of 90 per cent. relative humidity, depending upon the temperature. The eggs were unable to absorb water lost by evaporation except when liquid water was in contact with the shell. There were slight but significant differences between the rates at which water was lost through the shell, under similar conditions, at different stages during development. The eggs lost water most slowly during diapause and most rapidly either when first laid, or when about to hatch.

The final survey of the distribution and abundance of crickets in the South-East was made in April, 1952. It has been pointed out in earlier reports that crickets reach swarm numbers, and cause serious pasture damage, only on low-lying, heavy, rendzina-type clay soils which are water-logged in winter. The conclusions reached from the surveys of 1949, 1950 and 1952 and from the experimental work with eggs and adults, are as follows. The number of crickets has been tending to increase since the rendzina soil areas of the South-East were first settled and drained. This results from a great increase in the amount of food available to the crickets in the form of sown permanent pastures. This

trend appears likely to continue in the future with the consequence that crickets may be expected to become a more serious pest, spread over a wider area, as the development of swamp soils in this area progresses.

2. ARMYWORMS.

At least three species of swarming caterpillars which behave as "armyworms" (*Persectania ewingii* Westw., *Pseudaletia australis* Franch., and *Dasygaster hollandiae* Guen.), are responsible for heavy losses of cereal crops and pastures at irregular intervals in South Australia. The caterpillars of the three species resemble each other closely in colour, pattern and pigmentation, and it is not clear whether past outbreaks should be referred to one, two or all three species.

An investigation was commenced in 1952 to study the biology of these insects, their relative abundance and economic importance, and the factors that control their population densities. Results obtained so far show that most damage is done by *P. ewingii*, but that on Kangaroo Island and southern Yorke Peninsula, *Pseudaletia australis* may also be important. The annual life-cycle of *P. ewingii* has been worked out, and the characters established by which the early stages may be recognized. Three broods a year occur under favourable weather conditions, and the degree of survival appears to be closely dependent on the rainfall pattern. Economic damage results from the first brood (pastures and young cereal crops in "early" districts) and from the second brood (maturing cereal crops, chiefly barley, in later districts).

During the course of the work it has been found that a number of parasitic wasps and flies play a part in limiting the numbers of armyworms; some twenty distinct species have been encountered so far. In addition, a granulosis-type virus disease of *Persectania* was found to cause a rapid general mortality in a swarming population of larvae at Cherry Gardens during the spring of 1952; this is the first insect granulosis virus to be reported from Australia. The work on armyworms is proceeding.

3. PHYLLOXERA.

The grape phylloxera (*Dactylosphaera vitifolii* (Fitch)) which is of North American origin, spread during the last century to all the principal vine-growing countries of the world. It was first recognized in Australia in 1877 at Geelong, and some years later reached the Rutherglen district, then the principal vineyard area in Victoria. It also reached the Sydney district and a localized occurrence near Brisbane has been reported. In these localities vine growing has, in general, been continued on resistant stocks, which are obtained from North American species of *Vitis* that tolerate infestation by the insect. Phylloxera remains permanently established in these districts; if European vines are planted there upon their own roots, they become infested and ultimately die.

As far as can be determined there has been no further enlargement of the areas where Phylloxera is established since early in the present century. South Australia has, however, maintained a prohibition upon the importation of vine materials into the State, which maintains some forty-five per cent. of total Australian plantings.

Very little information has been published on the entomological aspects of the occurrence of Phylloxera in Australia. It was therefore considered desirable

that the insect should be studied in the field; with the co-operation of officers of the Victorian Department of Agriculture, an examination of the position in the Rutherglen district in north-eastern Victoria was commenced in 1953.

The life-cycle of *Phylloxera* is fully expressed on its native hosts, various North American species of *Vitis*. On the European vine, *Vitis vinifera*, only the root-feeding phase is developed; this maintains itself continuously by successive parthenogenetic generations, and bridges the winters by dormant larvae, the hibernants. Ultimately the death of the European host follows. Dispersal takes place underground from root-system to root-system, or by movement on the soil surface in soils that crack by shrinkage. The complete cycle takes place on American vines or their hybrids, and includes as well as the root cycle (1) leaf-living forms that produce galls on infested leaves; (2) winged forms that are produced from the root-infesting phase; (3) sexual males and females derived from eggs laid by (2); and (4) females, derived from winter eggs laid by (3), which lay eggs producing the leaf-gall formers of the ensuing summer.

Although leaf-galls were known to occur rather rarely on American vines in the Rutherglen district, no information was available about the remainder of the cycle under Australian conditions. Observations made so far show that at Rutherglen the subterranean cycle is maintained upon both species of vine, and newly-planted vines on their own roots are likely to be infested fairly rapidly. It was also established that on some American vines, notably upon the hybrid *riparia* x *rupestris* 3309, leaf-galls are produced freely. Nymphs bearing wing-buds were found among root-colonies on American vines, and later, winged forms were obtained. Evidence was also obtained of the presence of both the sexual eggs (laid by alates) and of winter eggs, upon the bark of the hybrid (3309) vines. It is therefore concluded that the complete life-cycle can express itself under the conditions prevailing in the Rutherglen district. The insect in general behaves normally, and its biological relationships appear to conform closely to those already reported for it in Europe and in other localities where it has become established.

4. OTHER INVESTIGATIONS.

A paper has been published upon the theoretical aspects of metamorphosis in insects, with special reference to the cross-relationships between the various post-embryonic phases of ametabolous, hemimetabolous, and holometabolous life-cycles.

A survey was begun of the introduced scale-insects of the State; a special study is being made of the mealy bug family (Pseudococcidae). A comprehensive catalogue to the literature relating to Australian Coccoidea has also been in preparation. Progress has also been made in a survey of the eriophyid mites; these cause a variety of distortions, russetings and shoot-damage, in both native and cultivated plants.

5. MISCELLANEOUS.

No new or introduced insect pests were recognized during the period under review. The eradication campaign against fruitflies in Adelaide suburbs was continued by the Department of Agriculture. The Mediterranean fruitfly, widespread in the period 1948-50, was not encountered; the Queensland fruitfly (*Dacus tryoni* (Frogg.)) was found in extremely localized occurrences in

January, 1952, and January, 1953, and again in September, 1953, when only a single female fly was trapped. A zone with a mile radius from each occurrence was cleared of host fruits, and various insecticidal treatments were maintained. Neither of these fruitflies has been found to occur elsewhere in South Australia.

In 1952 a committee was set up by the Commonwealth Government to enquire into the risk that siricid wasps might become established in Australian coniferous forests, due to their frequent occurrence in various kinds of imported softwoods and wooden structure. A member of the staff of the Department of Entomology was appointed as entomological member of the committee, which took evidence in all Australian States and New Zealand. A report was issued in which the available evidence was reviewed and recommendations for protective measures were presented (see bibliography).

Plant Pathology

At the close of 1951 this Department was brought up to full strength, and in February, 1953, it was further strengthened by the appointment of a special officer to undertake full-time investigations on the Gummosis Disease of Apricots. The three main functions of the Department, teaching, advisory and research have continued during the period under review without interruption.

1. GENERAL ADVISORY WORK.

A number of important economic diseases of agricultural and horticultural crops recur each year and demand considerable time and attention from the staff. It is not possible at any one time to carry out detailed investigations on more than a few of these under South Australian conditions, and in some instances the control measures applicable to South Australia are not known.

Cereals. Eelworm (nematode) attack is particularly severe on oats in the Keith-Bordertown area every year, but is generally distributed throughout the State.

"Bare Patch Disease", caused by *Rhizoctonia* is very common on the lighter soils of the State, and is capable of causing heavy loss in some fields. This disease is now being investigated in detail, both in field and laboratory.

Lucerne. The condition of "unthriftness" is fairly common, but so far has not been connected with any parasitic organism.

Subterranean clover. The fungus *Urophyllyctis alfalfae* occurs on low-lying, wet areas in the South-East districts.

Lawn Grasses. Considerable trouble has been experienced of recent years around Adelaide with "Brown Patch" and "Dollar Spot" diseases, due to *Rhizoctonia solani* and *Sclerotinia homeocarpa* respectively, damaging lawns, bowling and golf greens and playing fields. Research into these diseases is reported below.

Vegetables. Virus diseases in such crops as potatoes, tomatoes, carrots and cauliflowers continue to cause serious problems. The browning of vascular tissues, noted from time to time in the tubers of potatoes lifted for market, was definitely proved to be the result of infection by *Fusarium*.

Serious losses caused by *Verticillium* wilt continue to occur amongst glass-house tomatoes in Adelaide. Some commercial firms are now providing soil treatments, which appear promising in the degree of control obtained. In 1953 cases of leaf-spotting of glasshouse tomatoes could not be traced to any parasitic organism; they were very general in a few varieties planted out in late April and early May.

A canker of parsnip roots is probably due to attack by *Itersonilia* sp., but difficulty has been experienced in the isolation of this very slow-growing fungus from the specimens submitted.

Much damage to vegetables, such as celery, lettuce, carrots, etc., is caused in some seasons by *Sclerotinia*, the extent probably determined by local and temporary conditions of temperature and humidity, and hence exceedingly difficult to control.

Orchard Crops.

The shot-hole and bud-killing effects of *Clasterosporium* are very important both in the Adelaide area and in the River Murray districts, and a satisfactory degree of control is not always obtained by Bordeaux spraying in autumn and spring. The gummosis disease of apricots (*Cytosporina*) is dealt with below under research. Silver-leaf (*Stereum purpureum*) causes important damage in the orchards of the Adelaide Hills; the same fungus may possibly be responsible for the death of willows in Mypolonga and other districts.

Virus diseases of citrus are causing some concern: the "bud-union decline" was definitely proved to occur in a block of navel oranges at Renmark, the first definite record of its occurrence in the State. Other suspected virus diseases have been found in lemons in Adelaide and in other citrus in the River Murray area, but have not yet been confirmed or identified. The collar rot, due to *Phytophthora* is serious in back-gardens in Adelaide and is now regarded as much more important in the River Murray citrus orchards than it was previously thought to be. Its distribution in relation to watering and irrigation practices needs investigation, as modifications in these may prove to be the most practical way of prevention and control. Considerable losses are still experienced from storage spotting of oranges, partly due to the "latent infection" of *Alternaria* and *Colletotrichum*.

The problem of "dying vines" continues to be serious, and there is some evidence that attack by a species of *Pythium* may be partly responsible. Instances of suspected virus diseases of vines have been recorded during recent years, and it is hoped that in co-operation with the Department of Agriculture it may be possible to make a detailed survey of vineyards from this angle, preparatory to initiating detailed work on the suspected diseases.

Ornamentals.

Sclerotinia attack on *Gladiolus* is severe in the Adelaide area, and serious losses have occurred in some commercial nurseries. In the 1952-53 season roses were severely attacked by the virus of "wilt die-back", especially young nursery stock. More attention is necessary to the selection of healthy stocks for budding, as also to the sources of budwood.

Several cases of attack by *Monochaetia unicornis* on *Cupressus* spp. in Adelaide were found in 1952-53, these forming the first records of the occurrence of this fungus in the State.

2. PLANT QUARANTINE.

Regular inspections were made of several nurseries where ornamental plants imported from overseas are being grown under quarantine. The most troublesome disease found was the virus attack upon dahlias, necessitating the destruction of a proportion of young plants of newly-imported varieties. Many dahlia growers have complained of the increasing difficulty experienced in raising healthy plants. The quarantine areas of wheat varieties imported from New Zealand, at Kybybolite and Kangaroo Island were also inspected; a few lines were found to be heavily infected with loose smut. Phylloxera-resistant varieties of vines being grown under quarantine at Kangaroo Island are being checked closely for any sign of virus infection.

3. RESEARCH ACTIVITIES.

Rhizoctonia investigations.

A wide range of strains of *Pellicularia filamentosa* (= *Rhizoctonia solani*) varying either in pathogenic character or geographical distribution has been accumulated, and a technique developed whereby many of these strains have been induced to form their perfect stage. All these strains appear to be identical in this stage, and agree with the description given by Rogers. Two strains were found to form the perfect stage in cultures on agar, a feature recorded only once previously, and this has enabled a comparison to be made of their morphology on both artificial and natural substrates.

Cultures made from single basidiospores from the various strains have been studied; it was found that such isolates from a single parent strain vary as widely as the whole series of parent cultures themselves in cultural characters, but in general the pathogenic characters of the single-spore isolates are the same as those of their parent culture. Single-basidiospore cultures were found able to reproduce the perfect fruiting stage.

The factors governing the specificity of strains mentioned in the previous report have been further investigated by growing the host plants in soil inoculated with the appropriate strains of the fungus, but separating the host and pathogen by various membranes. Evidence is accumulating that the pre-penetration activity or "organization" of the fungus is governed by some chemical stimulus from the host, and that in response to this the fungus itself produces a diffusible substance which passes through the membrane and affects the host cells, finally killing them. The same technique is now being used successfully to investigate the post-penetration "hypersensitive" reaction described in the previous report.

Anastomoses between different pathogenic strains have been obtained; from the same two original parents a number of anastomoses have been obtained which differ markedly. In cultural characters they may resemble one or other parent strain more or less closely, but in pathogenicity may resemble either the same or the other parent, thus their cultural characters do not necessarily indicate their pathogenic behaviour. These cultures made from anastomoses between strains are being tested further, particularly with the hope of inducing fructification and of study of the resultant segregation of characters amongst the basidiospores.

In the field, where *P. filamentosa* causes the "bare patch" disease of cereals and of pasture grasses, ecological studies are in progress. Such bare patches have been mapped accurately in several fields, and new maps will be made for

the next few seasons, in the hope of tracing the developmental history of the individual patches. The occurrence of the fungus in the soil in relation to the bare patches is also under study, and it has been found amongst the healthy plants well removed from the nearest bare patch.

(2) *Brown Patch and Dollar Spot of Turf.*

The ecology and pathogenicity of *Pellicularia filamentosa* and of *Sclerotinia homeocarpa*, the fungi responsible for these diseases, have been studied. In culture both behave similarly with respect to growth rate, temperature range, pH and humidity. In nature both require similar conditions for infection to occur, but *S. homeocarpa* forms spots up to 2 ins. in diameter, whereas *P. filamentosa* causes patches up to 10 ft. in diameter. This difference in symptom expression is related to a difference in reaction to other soil organisms. The former fungus is unable to compete with these, whereas *P. filamentosa* is an efficient saprophyte.

In soil *P. filamentosa* produces runner hyphae with relatively few side branches, but in grass cuttings or in turf it forms a dense colony. This difference might explain why the fungus causes diseased patches in grass covers, whereas in a field crop such as cabbage it causes the "wire stem" disease as isolated instances and not in definite patches. Pathogenicity tests showed that both *P. filamentosa* and *S. homeocarpa* affect a wide range of host plants. The latter causes a severe stunting of the plants, but in most cases these are not actually penetrated by its hyphae, the stunting being caused by a water-soluble toxic substance liberated by the fungus. The growth of *P. filamentosa* is stimulated in the rhizosphere of susceptible plants, and the specificity of this stimulus is under investigation.

(3) *Virus Investigations.*

Work on the elucidation of the cause of the "decline" of cherry trees in the Adelaide Hills was continued. It has been found that the disease is due to a virus of which the varieties Napoleon and Beauchamps Black are almost symptomless carriers. It is readily transmitted by grafting from these varieties to several local seedling selections, particularly William's Favourite, on which it induces a severe necrosis. Work now in progress involves the determination of the actual virus involved in this disease, as well as in others suspected to occur amongst the same orchards, the host range of each, the effect of various stocks on the severity and progress of the disease in the scions used, and the development of a rapid and reliable indexing technique for testing and sorting commercial nursery material.

Investigation has continued on the method of seed transmission of plant virus diseases mentioned in the previous report. The most suitable viruses found for this work were cucumber and tobacco mosaics, though work with the former was severely handicapped until a technique was developed for its quantitative estimation by the use of the local lesion reaction of cowpea seedlings. A description of this technique has recently been published. The existence of substances in seeds which greatly reduce the infectivity of virus preparations, reported by previous workers, has been confirmed, but contrary to their conclusions, it has been found that the action of these substances is merely that of inhibiting virus infection, and they have not been found to exercise any true inactivation of the virus itself. Hence their existence offers no explanation of the rarity of plant virus transmission through the seed.

(4) *Studies on the Microflora of Australian Soils.*

Work of a preliminary nature has been carried out on the ecology of fungi in Australian soils. Some Northern Territory and Queensland soils are of interest in that they contain a high proportion of Ascomycetes, which are poorly represented in the southern soils examined. *Trichoderma*, *Fusarium* and *Aspergillus* are widely distributed in the latter, and the last genus is well represented in warmer arid soils. *Penicillium* species are abundant in cooler, acid, sandy soils and are less common generally in arid or alkaline soils. Several interesting species of *Aspergillus* and *Penicillium* have been isolated, and their taxonomic position is being investigated.

A simple technique for the isolation of mycelial fungi directly from soil has been devised. In an examination of a grassland soil by this method, several species of fungi were isolated, which were not obtained by standard dilution methods; a few species were abundant as mycelium, but poorly represented on dilution plates, while other species were not obtained as mycelium, but were abundant on the dilution plates. The method was also used successfully to isolate the root-pathogen *Rhizoctonia* directly from soil without the use of a host plant.

(5) *Fungal Gummosis of Apricots.*

In October, 1952, the State Government of South Australia agreed to maintain a full-time research officer at the Waite Institute to investigate this disease; the officer appointed commenced duty in February, 1953, and is working along three main lines:

- (a) Determination of the complete life-cycle of the pathogenic fungus, *Cytosporina* sp. Until recently it was suspected that an ascomycete, *Cryptovalsa* sp., of fairly common occurrence on dead apricot wood in South Australian orchards, might represent the perfect stage of the pathogen, but further work has established that it has no connection with *Cytosporina*, nor is it at all pathogenic to apricot trees.

All present information indicates that the spores of the *Cytosporina* stage of the pathogen cannot be induced to germinate in the laboratory, nor apparently can they cause infection of the apricot when inoculated on it; it is therefore inferred that even on the host plant these spores will not germinate. These spores are so far the only ones known to be produced by the pathogen, in spite of all efforts, both in the laboratory and in the orchard, to induce it to form other stages.

All fungi fruiting on dead branches of apricot, and on old prunings on the ground, are now being examined in detail, in an attempt to discover some naturally-occurring source of inoculum, in order to explain the spread of the disease.

- (b) Introduction of material of Apricot and related species from overseas. Hitherto about 250 seedlings have been raised from seed imported from Canada, England, Iraq, Poland and Sweden; these seedlings when grown to sufficient size, will be tested by inoculation for any signs of resistance to *Cytosporina*. No such resistance appears to be possessed by any variety of apricot now grown in Australia.
- (c) Investigation of pruning methods in relation to orchard infection. It has long been known that infection occurs only through wounds in the twigs and branches, and normally most of these wounds are caused through

pruning the trees. Work is now in progress to determine at what season, and for how long a period, such wounds are most susceptible to invasion by the parasite.

(6) *Mycology.*

The compilation has been undertaken of records, with such descriptions and notes as are available, of all fungi occurring in Australia, with a view to the eventual production of a Fungus Flora of Australia. It became evident at a very early stage that many of the older records are either incomplete or even incorrect, and it is now necessary to trace the specimens on which these records were based, if these are still extant, and to re-determine them in the light of modern knowledge. The mere compilation of the old records involves a detailed search through a large part of the literature on Australian agriculture, as well as of many other journals, both local and foreign, and hence cannot be completed rapidly. So far about 6,000 species of fungi have been included in these records, and large additions to this number are to be expected as the combing of literature proceeds, and as new records are made in Australian laboratories. The ultimate aim is not only to prepare a complete list of Australian Fungi, but also to include detailed descriptions, with drawings or paintings wherever possible, and at least the more important references to the literature of each species. Even with the assistance of collectors throughout Australia, and of specialists in the various groups of fungi represented here, the work is likely to occupy many years before it could be considered as sufficiently complete for publication. Meanwhile a start has been made in detailed examination of individual groups, of which one, the *Meliolaceae*, has already been completed and published up to date, though even here it is probable that further search by collectors, especially in New South Wales, Queensland and the Northern Territory, will bring to light many additional records. Hitherto it has not proved possible to arrange for collectors in New Guinea and Papua, both of which territories were included in Cooke's Handbook of Australian Fungi, published in 1892.

Rapid progress has been made towards the completion of a monograph of the *Meliolaceae* of the world, thanks to the ready and most valuable co-operation of the authorities in charge of the herbaria of the Royal Botanic Gardens, Kew, the National Museum, Stockholm, the Farlow Herbarium of Harvard University and the National Museum of Natural History, Paris. In addition to the regular consignments of specimens from these herbaria, a collection of about 2,000 specimens was received from the Herbarium Bogoriense, Indonesia; the results of examination of these are now in course of publication in Indonesia. Examination of the Kew collections has now been completed, and the majority of those of Stockholm. Two large collections still await examination, one in the U.S.A. and the other in South America; it is hoped that suitable arrangements can be made with their owners for re-examination of these in detail. It is estimated that the work may be completed during the next four or five years.

4. LEGUME SEED INOCULATION.

The demand for cultures of *Rhizobium* for legume seed inoculation has continued to increase, and over 5,000 cultures were distributed in 1953. In addition to this service, a search for superior strains of *Rhizobium* is being carried out. The necessity for field trials to evaluate the worth of cultures has been demonstrated, since some strains highly effective for subterranean clover in

glasshouse trials gave little response in the field. Amongst the field trials carried out on effectiveness of strains of *R. trifolii* on subterranean clover, it was found that one strain, originally isolated from Kangaroo Island, gave promising results in plots at Parndana there, and this strain is now being tested more widely.

Climatology

The accurate estimation of the amount of water required by crops, pastures and native vegetation is basal to the understanding of the effective use of rainfall and irrigation. Direct estimates of the water content of the soil have been made by sampling at Yudnapinna at monthly intervals over a period of some years. More frequent measurements in terms of the resistance of gypsum blocks were made on the plots of a simple crop rotation and under a perennial pasture during the period 1948-1951 and the data so obtained have since been the subject of interpretation and statistical examination. There is evidence that evapotranspiration from both a wheat crop and a pasture can be quantitatively related to the amount of available water, expressed as that stored in the soil profile plus that available as rainfall in any given month.

Further estimates of these water losses are possible in terms of physical principles involving the supply of solar energy and the turbulent transport of water vapour from the evaporating surface. The principles involved have been examined and checks made in the field on the estimates so obtained.

The meteorological factors concerned are sunshine, wind, temperature and atmospheric humidity, and these factors have been used in estimating the evaporation from a free water surface for the months of January and July over Australia.

It has been shown that the amount of solar energy available for evaporation and transpiration can be calculated with fair approximation from the recorded sunshine and the standard tables of solar radiation on a horizontal surface, as calculated for a transparent atmosphere.

Meteorological Records

Meteorological observations in connection with the work of the Waite Institute are being made at two centres: at the Waite Institute itself and at Yudnapinna (north-west of Port Augusta). The records for 1952 and 1953 are given in the following tables:

Monthly rainfall and evaporation (in.), number of rainy days and relative humidity for 1952 and 1953, Waite Institute.

Month	Rainfall		Number of Rainy days		Evaporation		Relative Humidity	
	1952	1953	1952	1953	1952	1953	1952	1953
January	1.58	1.52	6	4	8.32	8.70	45	46
February	0.22	0.53	3	2	6.87	7.62	56	44
March	0.24	0.09	5	4	6.54	7.65	50	42
April	3.02	1.51	16	11	4.00	4.15	64	59
May	5.43	1.56	21	10	2.01	2.81	74	62
June	2.22	5.77	18	23	1.42	1.74	83	73
July	2.02	4.02	15	18	1.75	1.83	71	73
August	1.99	2.81	13	22	2.20	1.75	71	73
September	1.24	2.17	15	12	3.28	3.05	65	63
October	2.14	1.65	15	10	3.80	4.66	62	55
November	4.74	1.86	18	13	4.63	5.92	64	52
December	0.78	1.99	9	6	6.79	6.50	51	46
Total	25.62	25.48	154	135	51.61	56.38	Mean 63	57

Mean monthly air temperatures (°F.) for 1952 and 1953, Waite Institute.

Month	Maximum		Minimum		Mean	
	1952	1953	1952	1953	1952	1953
January	81.8	81.4	60.1	60.6	71.0	71.0
February	77.1	81.1	57.4	61.4	67.2	71.2
March	79.9	82.7	60.2	60.8	70.0	71.8
April	66.6	72.0	51.7	57.3	59.2	64.6
May	61.8	65.2	50.5	50.5	56.2	57.8
June	59.1	58.4	48.1	48.4	53.6	53.4
July	56.5	57.5	43.6	46.3	50.0	51.9
August	58.3	56.1	44.4	45.2	51.4	50.6
September	63.7	62.8	48.0	47.9	55.8	55.4
October	66.1	68.2	50.5	51.3	58.3	59.8
November	68.8	71.2	52.6	52.9	60.7	62.0
December	75.8	76.7	55.2	56.6	65.5	66.6
Mean	68.0	69.4	51.9	53.3	59.9	61.3

Mean monthly soil temperatures (° F.) at 1 inch, 6 inches, 12 inches and 24 inches for 1952 and 1953, Waite Institute.

Month	1 in.		1 in.		6 in.		6 in.	
	Maximum		Minimum		Maximum		Minimum	
	1952	1953	1952	1953	1952	1953	1952	1953
January	102.7	104.9	64.0	63.1	83.8	83.3	71.0	69.7
February	103.4	101.8	60.7	63.5	82.5	83.8	68.9	70.1
March	100.8	101.8	60.7	61.8	79.1	81.7	67.6	68.8
April	78.5	80.7	51.9	57.0	66.3	70.6	58.2	62.9
May	64.9	71.0	49.6	48.9	58.3	61.4	53.5	55.2
June	60.3	61.5	47.7	46.9	55.3	55.3	51.9	51.4
July	59.4	60.9	42.7	43.7	51.8	53.6	47.2	48.7
August	61.6	60.1	45.2	43.9	54.5	53.6	49.4	48.9
September	69.9	73.5	49.0	47.0	60.6	60.9	53.6	52.7
October	76.4	83.6	52.1	51.8	65.4	68.0	57.6	58.3
November	82.1	91.6	54.6	54.6	70.2	74.0	60.4	62.4
December	96.1	95.7	59.5	58.6	77.8	77.6	66.0	66.1
Mean	79.7	82.3	53.1	53.4	67.1	68.7	58.8	59.6

Month	12 in.		12 in.		24 in.		24 in.	
	Maximum		Minimum		Maximum		Minimum	
	1952	1953	1952	1953	1952	1953	1952	1953
January	77.4	76.3	73.2	71.7	71.6	70.1	70.9	69.4
February	75.9	77.4	71.5	72.8	70.9	71.4	70.3	70.7
March	73.0	75.2	69.4	71.0	68.7	70.4	68.3	69.7
April	63.1	67.6	60.9	64.9	62.8	65.6	62.2	65.0
May	56.2	59.0	54.8	57.0	56.4	58.8	56.1	58.5
June	53.8	53.7	52.9	52.4	54.2	54.0	53.7	53.7
July	49.9	51.2	48.5	49.7	50.3	51.2	50.0	50.9
August	52.1	51.3	50.3	49.9	51.5	51.1	51.0	50.8
September	57.2	56.5	54.9	53.8	54.8	53.9	54.2	53.3
October	61.7	62.8	58.8	59.6	58.5	58.8	57.9	58.1
November	65.9	68.1	62.1	64.1	61.9	63.3	61.0	62.5
December	71.4	71.7	67.4	67.7	65.9	66.3	65.3	65.6
Mean	63.1	64.2	60.4	61.2	60.6	61.2	60.1	60.7

Wind velocity at 1.25 metres and 2 metres from the ground (in miles per day) from cup anemometers for 1952 and 1953, Waite Institute.

Month	1.25 Metres		2 Metres	
	1952	1953	1952	1953
January	78	87	88	101
February	74	80	85	93
March	74	78	86	90
April	74	59	85	70
May	71	61	82	70
June	66	86	76	98
July	70	75	79	98
August	73	80	82	91
September	90	96	103	110
October	80	84	91	96
November	90	91	104	104
December	87	76	101	86
Mean	77	79	88	92

GENERAL CLIMATOLOGICAL DATA.

The most important data on which are based studies of climatology as applied to agriculture and biology involve rainfall, evaporation, temperature and humidity.

Evaporation from a free water surface is dependent on temperature, humidity, sunshine and wind. Estimates of evaporation have usually been made in the work of the Waite Institute on the assumption that it is proportional to saturation deficit when comparisons made for two or more localities relate to the same month. The ratios of precipitation (rain, hail, snow and dew) to evaporation or saturation deficit have been found of special value in agro-climatological studies. A ratio of more universal application has been found to be that of precipitation to the 0.75th power of evaporation or atmospheric saturation deficit, and this ratio is being increasingly applied and tested. It can be assumed that monthly values of $1.2E^{.75}$ or 12 s.d.^{.75} correspond closely to the evaporation from a vegetated land surface with adequate but not over-abundant soil moisture. For drought-resistant crops at the lowest level of production the value is closer to $0.8E^{.75}$.

Climatological data for the Waite Institute. Means of 29 years, 1925-53.

Month	Rainfall inches	Evaporation inches	Number	Hours	Air temperature, ° F.	Max.	Min.	Mean
			of rainy days	Relative Humidity per cent.				
January	0.99	8.62	5.9	48	8.9	81.6	60.4	71.0
February	1.14	7.01	6.0	52	8.5	80.7	60.5	70.6
March	0.82	6.46	6.0	51	7.7	78.5	59.4	69.0
April	2.02	3.96	12.3	62	5.6	70.1	54.3	62.2
May	3.09	2.67	15.6	68	4.1	64.1	50.7	57.4
June	2.97	1.73	18.7	75	3.2	58.8	46.6	52.7
July	3.21	1.74	20.7	75	3.2	57.3	45.3	51.3
August	3.02	2.28	19.4	71	4.4	59.1	45.8	52.4
September	2.42	3.23	16.6	64	5.7	63.8	48.2	56.0
October	2.21	4.57	14.7	60	6.6	68.2	50.8	59.5
November	1.60	6.06	10.4	54	7.7	73.7	54.5	64.1
December	1.19	7.75	7.6	50	8.3	78.9	57.9	68.4
Total	24.68	56.08	153.9	Mean 61	6.2	69.6	52.9	61.2

Climatological data for the Waite Institute. Means of 29 years, 1925-1953, corrected to a standard month of 30.4 days.

Month	Rainfall inches	Evaporation (E) inches	Saturation Deficit (inches of mercury)	Water need of vegetation		
				low $0.8E^{.75}$ inches	moderate $1.2E^{.75}$ inches	high $1.6E^{.75}$ inches
January	0.97	8.45	.398	3.96	5.95	7.93
February	1.23	7.54	.362	3.64	5.46	7.28
March	0.80	6.33	.350	3.19	4.79	6.39
April	2.05	4.01	.215	2.27	3.40	4.53
May	3.03	2.62	.152	1.65	2.47	3.29
June	3.01	1.75	.100	1.22	1.83	2.44
July	3.15	1.71	.095	1.20	1.79	2.39
August	2.96	2.24	.115	1.46	2.20	2.93
September	2.45	3.27	.163	1.95	2.92	3.89
October	2.17	4.48	.205	2.46	3.69	4.93
November	1.62	6.14	.277	3.12	4.69	6.24
December	1.17	7.60	.350	3.66	5.49	7.32
Total	24.61	56.15	Mean .232	Total 29.78	44.68	59.57

Soil temperatures (° F.) at the Waite Institute. Means of 29 years, 1925-1953.

Month	1 in.		6 in.		12 in.		24 in.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	109.1	64.0	85.5	71.4	78.2	72.9	73.5	71.4
February	106.0	63.6	84.2	70.9	77.8	72.7	74.0	72.0
March	100.3	61.3	80.0	68.2	75.0	70.2	72.2	70.2
April	82.0	54.8	69.1	60.5	66.6	63.4	66.6	64.7
May	69.6	50.0	60.8	54.5	60.0	57.6	61.2	59.5
June	62.6	46.4	55.2	50.2	54.8	52.8	56.0	54.8
July	60.8	45.3	53.5	48.5	52.9	50.8	53.7	52.5
August	64.3	46.3	55.8	49.9	54.1	52.1	54.2	52.8
September	73.1	49.4	61.9	53.8	58.7	55.4	57.3	55.7
October	82.9	53.7	68.9	58.4	64.0	60.1	61.6	59.8
November	94.2	58.5	76.6	64.0	70.0	65.4	66.4	64.4
December	103.9	62.3	82.6	68.9	75.1	70.1	70.8	68.7
Mean	84.1	54.6	69.5	59.9	65.6	62.0	64.0	62.2

RECORDS AT YUDNAPINNA

Monthly rainfall and evaporation (in.), number of rainy days and relative humidity for 1952 and 1953, Yudnapinna.

Month	Rainfall		Number of Rainy days		Evaporation		Relative Humidity	
	1952	1953	1952	1953	1952	1953	1952	1953
January	1.31	1.82	6	3	14.49	15.82	49	47
February	—	0.28	—	3	12.93	11.82	56	56
March	0.33	0.11	2	1	12.11	11.97	58	49
April	0.77	0.04	8	3	7.84	8.41	66	60
May	2.98	0.04	12	4	3.64	4.91	83	72
June	0.84	1.12	4	9	2.58	2.56	90	81
July	0.70	0.48	7	6	2.52	2.86	86	81
August	0.17	0.96	3	14	3.55	3.39	82	69
September	0.38	0.61	5	11	7.64	5.63	56	56
October	1.07	0.73	10	11	8.76	7.55	57	44
November	0.91	0.46	7	5	10.86	10.67	48	38
December	0.20	0.71	3	8	14.35	11.62	46	38
Total	9.66	7.36	67	78	101.27	97.21	Mean 65	58

Mean monthly air temperatures (° F.) for 1952 and 1953, Yudnapinna.

Month	Maximum		Minimum		Mean	
	1952	1953	1952	1953	1952	1953
January	93.9	91.8	63.3	62.6	78.6	77.2
February	87.9	89.8	61.3	62.7	74.6	76.3
March	88.0	91.9	58.7	59.9	73.4	75.9
April	73.8	80.6	49.6	52.9	61.7	66.8
May	66.6	70.0	46.2	40.2	56.4	55.1
June	63.9	63.5	40.0	41.8	52.0	52.7
July	59.5	62.8	35.4	35.5	47.5	49.1
August	64.2	63.6	37.0	40.7	50.6	52.3
September	73.5	73.1	43.7	44.7	58.6	58.9
October	74.3	77.6	48.8	50.4	61.6	64.0
November	80.2	83.7	54.7	54.9	67.5	69.3
December	88.4	90.3	58.5	61.4	73.6	75.8
Mean	76.2	78.2	49.8	50.6	63.0	64.4

Wind velocity (in miles per day) from cup anemometers at 2 metres from the ground for 1951-1953, Yudnapinna.

Month	1951	1952	1953
January	154	145	178
February	156	174	153
March	134	132	129
April	103	121	92
May	86	87	75
June	63	75	89
July	89	69	81
August	102	98	96
September	105	117	118
October	147	127	91
November	148	151	98
December	143	168	103
Mean	119	122	109

Climatological data for Yudnapinna. Means of 15 years, 1939-53.

Month	Rainfall inches	Evaporation inches	Relative Humidity per cent.	Air temperature, °F.		
				Max.	Min.	Mean
January	0.72	14.60	45	92.3	63.4	77.8
February	1.21	11.58	50	89.1	63.2	76.1
March	0.54	10.46	49	85.9	59.0	72.5
April	0.38	6.73	60	75.4	51.6	63.5
May	0.91	4.32	68	68.6	46.3	57.4
June	0.98	2.58	78	62.7	40.9	51.8
July	0.68	2.95	76	61.5	39.2	50.3
August	0.52	4.10	68	65.9	40.7	53.3
September	0.42	6.50	54	72.7	45.1	58.9
October	0.82	8.92	48	77.4	50.6	64.0
November	0.72	11.09	44	83.9	56.1	70.0
December	0.84	13.19	41	89.9	61.0	75.4
Total	8.74	97.02	Mean 57	77.1	51.4	64.2

Climatological data for Yudnapinna. Means of 15 years, 1939-53, corrected to a standard month of 30.4 days.

Month	Rainfall inches	Evaporation inches	Saturation Deficit
			inches of mercury
January	0.71	14.32	.529
February	1.30	12.46	.454
March	0.53	10.26	.411
April	0.39	6.82	.236
May	0.89	4.24	.152
June	0.99	2.61	.085
July	0.67	2.89	.088
August	0.51	4.02	.131
September	0.43	6.59	.231
October	0.80	8.75	.313
November	0.73	11.24	.414
December	0.82	12.93	.523
Total	8.77	97.13	Mean .297

Soil temperatures (° F.) at 1 inch and 12 inches and air temperatures (° F.) at Yudnapinna. Means of 8 years, 1946-1953.

Month	1 inch		12 inches		Air temperature		
	Max.	Min.	Max.	Min.	Max.	Min.	Mean
January	115.7	66.4	91.0	79.5	92.8	62.9	77.8
February	110.1	65.3	89.6	77.9	89.1	62.9	76.0
March	105.1	60.6	86.0	74.6	85.6	58.2	71.9
April	88.7	52.6	75.9	65.5	75.4	50.1	62.7
May	77.3	47.1	67.7	57.8	69.0	45.2	57.1
June	66.7	41.6	61.0	50.2	62.4	39.6	51.0
July	67.2	40.7	58.6	47.3	62.2	37.8	50.0
August	73.3	44.2	61.7	51.1	66.3	39.6	52.9
September	84.3	50.0	68.8	57.9	73.2	44.1	58.6
October	92.8	55.6	75.1	63.1	76.8	49.4	63.1
November	102.4	61.1	81.9	69.9	83.5	55.3	69.4
December	114.7	65.3	87.9	76.7	89.5	60.3	74.9
Mean	91.5	54.2	75.4	64.3	77.2	50.4	63.8

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University of Adelaide, 1952-1953

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- K. Woodroffe and C. H. Williams. "The Residual Effect of Superphosphate in Soils Cultivated for Wheat in South Australia." *Aust. Jour. of Agric. Res.* 4: 127-150. 1953. (Reprint 584.)
- Helen M. Ferres. "Influence of Light and Temperature on Nutrient Uptake and Use, with Particular Reference to Zinc." *Brit. Comm. Sci. Off. Conf.—Aust. Session B*: 240-243. 1949. (Reprint 601.)
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(a) SOIL CHEMISTRY.

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- C. S. Piper and J. A. Prescott. "Factors Determining the Amount and Availability of Plant Foods in Soils." *Brit. Comm. Sci. Off. Conf.—Aust. Session A*: 72-79. 1949. (Reprint 599.)
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Records of Field Experimental Work

I. PERMANENT ROTATION EXPERIMENT, 1926-1953. (C1)

Effect of different crop rotations on the yield of wheat.

Variety of crop and seed rate per acre: Sepoy wheat (1926-34), Seewari 48 (1948-53), 80-90 lb.; Early Burt oats, 60-70 lb.; Prior barley, 70-80 lb.; White Brunswick peas, 120-150 lb.; Wimmera rye-grass, 10-15 lb. (1926-45), and Wimmera rye-grass, 3 lb. + Fulghum oats, 40 lb. (1946-53) on the rotations wheat, pasture, fallow and wheat, oats, pasture, fallow; Wimmera rye-grass, 3 lb. + subterranean clover, 6 lb. on the rotations wheat, 2 years of pasture and wheat, 2 years of pasture, fallow; phalaris, 3 lb. + subterranean clover, 6 lb. + lucerne, 1 lb. + Wimmera rye-grass, $\frac{1}{2}$ lb. on the rotation wheat, wheat, 4 years pasture, and the permanent pasture.

Basal dressing of superphosphate, 187 lb. per acre (1929-42), 94 lb. per acre (1944-53).

Design: Unreplicated, but each course of each rotation is represented each year.

Area of each plot = $1\frac{1}{7}$ acre (1926-37), $1\frac{1}{7}\cdot619$ acre (1938-53). Total yields in all cases are based on air-dry weights.

TABLE I

MEAN YIELDS OF CROPS IN EACH ROTATION IN 1952 AND 1953, AND OVER THE DURATION OF THE EXPERIMENT (FIGURES IN BRACKETS INDICATE THE NUMBER OF YEARS FOR WHICH REPRESENTATIVE YIELDS ARE AVAILABLE).

Rotation	Grain, bushels per acre				Total produce, cwt. per acre			
	Wheat	Barley	Oats	Peas	Wheat	Barley	Oats	Peas
1952								
Wheat, fallow	16.8	—	—	—	21.1	—	—	—
Wheat, peas	35.2	—	—	*	33.2	—	—	—
Wheat, barley, peas	38.4	—	—	24.3	40.0	—	—	23.3
Wheat, oats, fallow	21.9	—	34.1	—	25.6	31.1	—	25.7
Wheat, pasture, fallow	28.6	—	—	—	31.4	—	30.5	—
Wheat, 2 years pasture: 1st year	42.0	—	—	—	43.6	—	—	—
2nd year	—	—	—	—	—	—	—	—
Wheat, 2 years pasture, fallow: 1st year	51.4	—	—	—	60.0	—	—	—
2nd year	—	—	—	—	—	—	—	—
Wheat, oats, pasture, fallow	37.6	—	31.2	—	45.2	—	33.3	—
Wheat, wheat, 4 years pasture: 1st year	53.2	—	—	—	61.4	—	—	—
2nd year	**	—	—	—	**	—	—	—
3rd year	—	—	—	—	—	—	—	—
4th year	—	—	—	—	—	—	—	—
Wheat continuously	24.8	—	—	—	27.3	—	—	—
Permanent pasture	—	—	—	—	—	—	—	77.3

* No record.

** Duration of the rotation not long enough for the results to be representative.

I. PERMANENT ROTATION EXPERIMENT, 1926-1953. (C1)—continued.

Rotation	Grain, bushels per acre				Total produce, cwt. per acre			
	Wheat	Barley	Oats	Peas	Wheat	Barley	Oats	Peas
1953								
Wheat, fallow	9.6	—	—	—	18.6	—	—	—
Wheat, peas	11.7	—	—	1.0	17.4	—	—	—
Wheat, barley, peas	18.3	9.6	—	2.2	11.6	14.8	—	21.2
Wheat, oats, fallow	17.1	—	2.7	—	25.5	—	14.9	14.3
Wheat, pasture, fallow	12.6	—	—	—	17.7	—	—	—
Wheat, 2 years pasture: 1st year	31.0	—	—	—	35.7	—	—	—
2nd year	—	—	—	—	—	—	—	—
Wheat, 2 years pasture, fallow: 1st year	29.3	—	—	—	43.6	—	—	—
2nd year	—	—	—	—	—	—	—	—
Wheat, oats, pasture, fallow	31.8	—	—	—	41.6	—	—	—
Wheat, wheat, 4 years pasture: 1st year	11.7	—	10.0	—	22.8	—	15.7	—
2nd year	19.0	—	—	—	26.3	—	—	—
3rd year	—	—	—	—	—	—	—	—
4th year	—	—	—	—	—	—	—	—
Wheat continuously	0.6	—	—	—	13.5	—	—	—
Permanent pasture	—	—	—	—	—	—	—	100.1
Mean yield to 1953†								
Wheat, fallow	32.7(28)	—	—	—	47.8(28)	—	—	—
Wheat, peas	24.7(28)	—	—	18.7(26)	35.8(28)	—	—	—
Wheat, barley, peas	28.4 (2)	21.4(2)	—	13.2 (2)	25.8 (2)	23.0(2)	—	28.5(28)
Wheat, oats, fallow	33.4(27)	—	35.8(27)	—	51.6(27)	—	35.6(27)	20.0 (2)
Wheat, pasture, fallow	38.2(27)	—	—	—	53.7(27)	—	—	—
Wheat, 2 years pasture: 1st year	36.5 (2)	—	—	—	39.6 (2)	—	—	—
2nd year	—	—	—	—	—	—	—	—
Wheat, 2 years pasture, fallow: 1st year	40.4 (2)	—	—	—	51.8 (2)	—	—	—
2nd year	—	—	—	—	—	—	—	—
Wheat, oats, pasture, fallow	43.9(26)	—	46.8(26)	—	63.4(26)	—	43.5(26)	29.8(26)
Wheat, wheat, 4 years pasture: 1st year	32.4 (2)	—	—	—	42.1 (2)	—	—	23.8 (2)
2nd year	19.0 (1)	—	—	—	26.3 (1)	—	—	54.8 (2)
3rd year	—	—	—	—	—	—	—	46.4 (2)
4th year	—	—	—	—	—	—	—	80.3 (1)
Wheat continuously	13.3(28)	—	—	—	25.3(28)	—	—	32.6(26)
Permanent pasture	—	—	—	—	—	—	—	**
								**
								**
								**
								88.7 (2)

** Duration of the rotation not long enough for the results to be representative.

† This table does not agree entirely with the corresponding table in the 1950-51 report, as non-representative yields (i.e. those not preceded by a full cycle) have been excluded. In particular in the wheat, barley, peas, rotation the years preceding the break in continuity (1926-47) have been excluded.

TABLE 2
YIELD AND BOTANICAL COMPOSITION OF PASTURE PLOTS, 1952 AND 1953. (AIR-DRY WEIGHTS, CWT. PER ACRE).

Rotation	Total	Sown Species					Volunteer Species		
		W.R.G.	Sub. Clover	Phalaris	Lucerne	Grazing Oats	Annual Legumes	Annual Grass	Miscel- laneous
1952	45.4	1.4	—	—	—	44.0	—	—	Tr.
Wheat, pasture, fallow	10.2	1.5	7.1	—	—	—	—	0.5	1.1
Wheat, 2 years pasture; 1st year	57.9	35.5	11.6	7.2	—	—	—	1.8	1.8
Wheat, 2 years pasture; 2nd year	42.8	21.4	Tr.	—	—	—	—	10.7	10.7
Wheat, 2 years pasture, fallow: 1st year*	54.5	20.8	3.9	18.0	Tr.	—	—	3.1	8.7
Wheat, 2 years pasture, fallow: 2nd year*	30.4	0.6	—	—	Tr.	27.0	—	—	2.8
Wheat, oats, pasture, fallow	35.1	1.8	Tr.	—	—	—	—	Tr.	33.3
Wheat, wheat, 4 years pasture: 1st year*	62.5	6.1	38.9	4.0	10.2	—	—	1.7	1.6
Wheat, wheat, 4 years pasture: 2nd year*	92.8	8.9	4.4	5.1	5.8	—	—	63.4	5.2
Wheat, wheat, 4 years pasture: 3rd year*	88.7	Tr.	Tr.	79.8	0.1	—	—	8.8	Tr.
Wheat, wheat, 4 years pasture: 4th year*	77.3	32.1	17.0	17.4	1.0	—	—	9.7	0.1
Permanent pasture									
1953	22.8	4.2	—	—	—	14.5	—	3.0	1.1
Wheat, pasture, fallow	37.3	2.2	Tr.	Tr.	—	—	Tr.	33.6	1.5
Wheat, 2 years pasture: 1st year	51.8	25.8	15.7	Tr.	—	—	Tr.	Tr.	10.3
Wheat, 2 years pasture: 2nd year	49.9	21.6	Tr.	—	—	—	10.2	18.1	—
Wheat, 2 years pasture, fallow: 1st year	80.3	47.1	6.6	Tr.	—	—	Tr.	25.3	1.3
Wheat, 2 years pasture, fallow: 2nd year	24.4	2.0	—	—	—	4.8	17.6	—	Tr.
Wheat, oats, pasture, fallow	31.3	5.0	1.3	2.6	—	1.3	15.5	5.6	—
Wheat, wheat, 4 years pasture: 1st year*	67.9	52.0	4.5	11.4	—	—	—	Tr.	Tr.
Wheat, wheat, 4 years pasture: 2nd year*	91.5	8.5	Tr.	7.3	34.0	—	Tr.	41.7	Tr.
Wheat, wheat, 4 years pasture: 3rd year*	83.1	Tr.	1.8	0.9	23.0	—	Tr.	55.9	1.5
Wheat, wheat, 4 years pasture: 4th year*	100.1	13.3	10.0	41.5	19.3	—	—	16.0	Tr.
Permanent pasture									

* These yields are given for record purposes only; they are not representative of the rotation as a whole, as they have not been preceded by a full cropping cycle.

II. INFLUENCE OF GRAZED AND HARVESTED FORAGE CROPS ON THE YIELD OF TEMPORARY PASTURE AND WHEAT IN FOUR-COURSE ROTATIONS, 1937-1953. (C.53)

Present rotations:

1	2	3	4	5
Fallow Wheat Fallow Wheat	Fallow Wheat Oats Pasture†	Fallow Wheat Oats* Pasture†	Fallow Wheat Peas Pasture†	Fallow Wheat Peas Grazing Oats

* With sulphate of ammonia added.

† Wimmera rye-grass.

Variety of crop and seed rate per acre: Seewari 48 wheat, 80-90 lb.; Mulga oats, 60-70 lb.; White Brunswick peas, 120-150 lb.; Fulghum grazing oats, 60-70 lb.; Wimmera rye-grass, 10 lb.

Fertilizer: Basal superphosphate applied at 1 cwt. per acre. Sulphate of ammonia at 2 cwt. per acre applied to oats on rotation 3 at seeding.

Design: 60 main plots in 4 groups of 15 plots, each group representing one course of the rotations. The groups of 15 plots are divided into 3 randomized blocks in which each rotation is represented by a plot. The plots are subdivided into halves; one half the forage crop is grazed and on the other it is harvested.

Area of main plots = 1/6.94 acre.

Yields in all cases based on air-dry weights.

TABLE 3
MEAN YIELDS OF CROPS FOR EACH ROTATION IN 1952 AND 1953.

Rotation	Management of 2nd course	Grain, bushels per acre			Total produce, cwt. per acre			
		Wheat	Oats	Peas	Wheat	Oats	Peas	Pasture
1952								
Wheat, fallow	grazed	37.7	—	—	48.8	—	—	—
Wheat, oats, pasture, fallow	—	32.6	—	—	41.8	—	—	—
Wheat, oats + S/A, pasture, fallow	grazed	43.0	—	—	55.1	20.6	—	5.5
Wheat, oats + S/A, pasture, fallow	harvested	34.4	12.8	—	43.1	10.0	—	4.0
Wheat, oats + S/A, pasture, fallow	grazed	45.5	—	—	57.7	74.0	—	5.2
Wheat, oats + S/A, pasture, fallow	harvested	35.0	70.4	—	43.7	62.2	—	2.7
Wheat, peas, pasture, fallow	grazed	55.8	—	—	73.1	—	36.9	36.9
Wheat, peas, pasture, fallow	harvested	42.9	—	31.4	55.2	—	34.8	21.9
Wheat, peas, grazing oats, fallow	grazed	62.6	—	—	82.6	50.1	48.1	—
Wheat, peas, grazing oats, fallow	harvested	45.5	—	36.1	58.4	34.2	38.1	—
1953								
Wheat, fallow	grazed	15.7	—	—	19.0	—	—	—
Wheat, oats, pasture, fallow	—	16.7	—	—	20.0	—	—	—
Wheat, oats, pasture, fallow	grazed	30.4	—	—	33.9	2.5	—	6.8
Wheat, oats + S/A, pasture, fallow	harvested	30.3	1.9	—	33.3	2.5	—	5.6
Wheat, oats + S/A, pasture, fallow	grazed	36.6	—	—	41.3	17.7	—	7.3
Wheat, oats + S/A, pasture, fallow	harvested	30.6	21.3	—	34.2	21.2	—	7.2
Wheat, peas, pasture, fallow	grazed	32.9	—	—	40.7	—	25.0	11.4
Wheat, peas, pasture, fallow	harvested	28.5	—	5.0	33.6	—	8.4	11.0
Wheat, peas, grazing oats, fallow	grazed	37.3	—	—	44.0	28.2	32.0	—
Wheat, peas, grazing oats, fallow	harvested	36.4	—	9.7	41.7	26.1	12.5	—

TABLE 4
MEAN YIELDS OF CROPS FOR THE DURATION OF THE EXPERIMENT*.

Rotation	Management of 2nd course	Grain, bushels per acre			Total produce, cwt. per acre			
		Wheat	Oats	Peas	Wheat	Oats	Peas	Pasture
To 1948*								
Wheat, fallow	grazed	31.8(12)	—	—	45.4(12)	—	—	—
Wheat, oats, pasture, fallow	—	30.7(12)	—	—	44.6(12)	—	—	14.0(9)
Wheat, oats, and S/A, pasture, fallow	grazed	35.0 (9)	—	—	50.2 (9)	16.5(9)	—	9.9(9)
Wheat, peas, pasture, fallow	harvested	32.9 (9)	16.1(9)	—	47.2 (9)	15.0(9)	—	25.2(2)
Wheat, peas, pasture, fallow	grazed	—	—	—	—	39.2(3)	—	9.2(2)
Wheat, peas, pasture, fallow	harvested	—	35.8(3)	—	—	36.5(3)	—	58.6(9)
Wheat, peas, grazing oats, fallow	grazed	43.3 (9)	—	—	65.4 (9)	—	50.3(9)	35.2(9)
Wheat, peas, grazing oats, fallow	harvested	40.0 (9)	—	30.8(9)	59.3 (9)	60.8(2)	36.6(9)	—
Wheat, peas, grazing oats, fallow	grazed	—	—	—	—	40.6(2)	55.1(3)	—
Wheat, peas, grazing oats, fallow	harvested	—	—	42.2(3)	—	—	47.0(3)	—
1949-53								
Wheat, fallow	grazed	26.9	—	—	35.0	—	—	—
Wheat, oats, pasture, fallow	—	25.1	—	—	32.7	—	—	—
Wheat, oats, pasture, fallow	grazed	33.2	—	—	40.5	8.6	—	6.8
Wheat, oats, + S/A, pasture, fallow	harvested	30.3	6.2	—	37.2	5.2	—	5.3
Wheat, peas, pasture, fallow	grazed	37.4	—	—	45.5	35.8	—	8.8
Wheat, peas, pasture, fallow	harvested	31.9	38.3	—	38.6	34.4	—	5.2
Wheat, peas, pasture, fallow	grazed	44.2	—	—	55.8	—	40.4	27.9
Wheat, peas, grazing oats, fallow	harvested	37.5	—	19.4	46.8	—	23.9	19.2
Wheat, peas, grazing oats, fallow	grazed	45.9	—	—	58.5	46.5	46.9	—
Wheat, peas, grazing oats, fallow	harvested	40.9	—	25.9	51.1	35.8	30.1	—

* The experiment was started in 1936. In 1945 some of the rotations were altered. The running means are given in 2 parts. In the first part, up to and including the 1948 season, only those results were taken into account which were preceded by at least one full cycle of the present rotation; the number of years on which these means are based are given in brackets. From 1949 onwards all the rotations were represented each year and the running means given in the second part of the table are, therefore, strictly comparable.

TABLE 5

YIELD AND BOTANICAL COMPOSITION OF PASTURE PLOTS, 1952 AND 1953 (AIR-DRY WEIGHTS, CWT. PER ACRE).

Rotation	Management of 2nd course	Total Yield	Botanical Composition	
			W.R.G.	* Miscellaneous
1952				
Wheat, oats, pasture, fallow	grazed	5.5	4.0	1.5
	harvested	4.0	2.9	1.1
Wheat, oats and S/A, pasture, fallow	grazed	5.2	3.5	1.7
	harvested	2.7	1.0	1.7
Wheat, peas, pasture, fallow	grazed	36.9	34.5	2.4
	harvested	21.9	19.0	2.9
1953				
Wheat, oats, pasture, fallow	grazed	6.8	0.6	6.2
	harvested	5.6	0.1	5.5
Wheat, oats and S/A, pasture, fallow	grazed	7.3	1.1	6.2
	harvested	7.2	0.4	6.8
Wheat, peas, pasture, fallow	grazed	11.4	6.2	5.2
	harvested	11.0	5.9	5.1

* Mostly *Polygonum aviculare* with some *Avena fatua*.

TABLE 6

YIELDS OF WHEAT, 1949-53.*

Rotation	1949	1950	1951	1952	1953
<i>I. Grain, bushels/acre</i>					
Wheat, fallow	(±1.20) 40.4	(±1.79) 28.7	(±1.59) 9.5	(±0.91) 35.1	(±1.12) 16.2
Wheat, oats, pasture, fallow	37.7	32.5	19.4	38.6	30.3
Wheat, oats and S/A, pasture, fallow	41.2	37.0	21.3	40.2	33.6
Wheat, peas, pasture, fallow	53.5	48.2	22.6	49.5	30.7
Wheat, peas, grazing oats, fallow	54.2	48.5	23.3	54.1	36.9
Significant differences: 5%	3.9	5.8	5.2	3.0	3.7
1%	5.7	8.6	7.5	4.3	5.3
0.1%	8.6	12.7	—	6.5	8.0
<i>II. Total produce, cwt./acre</i>					
Wheat, fallow	(±1.37) 49.2	(±2.35) 34.8	(±2.42) 20.5	(±1.34) 45.3	(±1.18) 19.5
Wheat, oats, pasture, fallow	45.7	39.1	26.6	49.1	33.6
Wheat, oats and S/A, pasture, fallow	50.4	44.6	26.8	50.7	37.8
Wheat, peas, pasture, fallow	64.7	61.8	28.8	64.2	37.2
Wheat, peas, grazing oats, fallow	66.0	62.2	32.6	70.5	42.8
Significant differences: 5%	4.5	7.7	—	4.4	3.8
1%	6.5	11.1	—	6.3	5.6
0.1%	9.8	16.8	—	9.5	8.4

* Averaged over the 'grazed' and 'harvested' treatments.

III. INFLUENCE OF PASTURES AND FORAGE CROPS ON THE YIELD OF WHEAT GROWN IN ROTATIONS OF VARYING DURATION (192).

Combined field crop-pasture rotational experiment begun in 1947 with the object of comparing two-course and four-course rotations and an eight-course rotation, based on (1) Fallow, wheat; (2) Peas (grazed), wheat; (3) Pasture for two years, fallow, wheat; (4) Pasture for three years, wheat; (5) Pasture for six years, wheat, wheat.

The field had previously been subjected to a long period of wheat, bare fallow; and the investigations provide scope for examining the effects of the rotations on the nitrogen status and physical properties of the soil, as well as on forage and crop production.

Variety of crop and seed rate per acre; Seewart 48 wheat, 80-90 lb.; White Brunswick peas, 120-150 lb. Pasture mixture of *Bacchus Marsh* subterranean clover, phalaris, *Wimmera* rye-grass, lucerne. Basal superphosphate 112 lb. per acre per annum with each season of crop and of pasture.

All five of the rotations were commenced in each of the three seasons 1947, 1948, 1949. Those begun in 1949 were originally established in 1946 but not proceeded with until 1949; they have thus had an advantage of three seasons' rest from cropping, and this is apparent in the yields from this set.

Total of 30 plots, each 2.00×0.40 chains ($1/12.5$ acre), made up of rotations (5) $\times$ seasons (3) $\times$ replications (2).

TABLE 7

MEAN YIELDS OF CROPS FOR EACH ROTATION, 1952 AND 1953.

Rotation	Grain, bush. per acre		Total produce, cwt. per acre					
	Wheat	Peas	Pasture 1st year	2nd year	3rd year	4th year	5th year	6th year
1952								
Wheat, fallow	31.3	—	—	—	—	—	—	—
Wheat, peas (grazed)	36.2	57.2	—	—	—	—	—	—
Wheat, 2 years pasture, fallow	41.2	—	27.0	74.0	—	—	—	—
Wheat, 3 years pasture	42.7	—	12.7	69.5	—	—	—	—
Wheat, wheat, 6 years pasture	—	—	—	—	—	80.1	68.8	75.2
1953								
Wheat, fallow	16.9	—	—	—	—	—	—	—
Wheat, peas (grazed)	23.5	53.7	—	—	—	—	—	—
Wheat, 2 years pasture, fallow	—	—	53.1	67.6	—	—	—	—
Wheat, 3 years pasture	—	—	35.7	53.3	75.9	—	—	—
Wheat, wheat, 6 years pasture	14.4	—	—	—	—	—	78.9	83.7

TABLE 9

EFFECT OF 2 AND 4-COURSE ROTATIONS ON YIELD OF WHEAT.

Rotation	(Grain, bushels per acre)		
	1950 (± 0.93)	1951 (± 0.82)	1952 (± 2.13)
Wheat, fallow	18.1	20.9	48.7
Wheat, peas (grazed)	15.1	17.9	47.8
Wheat, pasture, pasture, fallow	49.8	28.6	41.3
Wheat, pasture, pasture, pasture	45.0	21.3	42.7
Mean	31.9	22.0	45.2
Least significant differences			
5%	4.1	3.7	9.5
1%	7.7	6.7	—
0.1%	17.0	—	—

IV. INFLUENCE OF TOP DRESSING ON THE YIELD AND CARRYING CAPACITY OF NATURAL PASTURES, 1925-1953. (P1)

Investigations commenced in 1925 on unimproved natural grassland dominated by *Danthonia* spp.
Manurial treatments:

Nil.

Basic slag, 260 lb. (40 lb. P_2O_5) per acre.

Ground rock phosphate, 103 lb. (40 lb. P_2O_5) per acre.

Superphosphate, 185 lb. (40 lb. P_2O_5) per acre.

Superphosphate, 185 lb., and nitrate of soda, 78 lb. ($12\frac{1}{2}$ lb. N) per acre.

Design: Unreplicated, single plot for each manurial treatment.

Area of plot: 13/15 acre subdivided into 4 equal sections grazed in rotation by Merino wethers

TABLE 10

INFLUENCE OF TOP DRESSING ON YIELD OF NATURAL PASTURE, 1925-53.

Year	Nil	Basic Slag	Rock Phosphate	Super- Phosphate	Super + N/Soda	Mean
I. Total produce, cwt. air-dry herbage/acre						
1952	58.3	98.5	84.8	71.8	82.4	79.2
1953	51.6	68.3	68.9	64.2	57.3	62.1
Mean 1925-35	31.1	47.2	39.3	45.6	50.2	42.7
1936-53	43.9	69.8	67.8	56.6	64.9	60.6
1925-53	39.1	61.2	57.0	52.4	59.3	53.8
II. Legumes, cwt. air-dry herbage/acre						
1952	16.2	7.6	0.8	2.0	2.2	5.8
1953	5.9	0.8	Tr.	8.5	0.4	3.1
Mean 1925-53	7.4	10.3	10.0	11.9	8.8	9.7
III. Stock carrying capacity, sheep days/acre						
1952	1657	2729	2698	2343	2682	2422
1953	1093	1778	1740	1355	1499	1493
Mean 1928-35	1066	1743	1404	1555	1823	1518
1936-53	1233	1929	1895	1749	1918	1745
1928-53	1182	1872	1744	1689	1888	1675

TABLE 11

YIELD AND BOTANICAL COMPOSITION OF PASTURE PLOTS, 1952 AND 1953 (AIR-DRY WEIGHTS, CWT. PER ACRE).

Treatment	Botanical Composition				
	Total	Danthonia	Annual Grasses	Annual Legumes	Miscellaneous
1952					
Nil	58.3	7.2	15.9	16.2	19.0
Basic slag	98.5	Tr.	55.3	7.6	35.6
Rock phosphate	84.8	Tr.	26.4	0.8	57.6
Superphosphate	71.8	0.7	31.7	2.0	37.4
Super. and N/Soda	82.4	Tr.	32.4	2.2	47.8
1953					
Nil	51.6	18.3	23.4	5.9	4.0
Basic slag	68.3	0.9	52.0	0.8	14.6
Rock phosphate	68.9	—	29.7	Tr.	39.2
Superphosphate	64.2	10.9	34.1	8.5	10.7
Super. and N/Soda	57.3	—	40.2	0.4	16.7

TABLE 12

INFLUENCE OF TOP DRESSING ON THE CARRYING CAPACITY OF NATURAL PASTURE; 1928-1953.

Sheep days per acre

	Nil	Basic Slag	Rock Phosphate	Super-Phosphate	Super + N/Soda
1928	705	1068	904	1152	1259
29	516	836	617	885	973
30	592	1043	667	813	1110
31	902	1355	1072	1271	1551
32	1762	2840	2208	2396	2635
33	1869	3176	2625	2724	3211
34	754	1370	1051	1250	1518
35	1429	2256	2084	1952	2324
36	705	1205	1328	1256	1402
37	1204	1768	1862	1656	1960
38	1466	2591	2494	2659	2768
39	1266	2629	2385	2224	2382
40	929	1002	1098	1090	1042
41	909	1108	1070	1029	1110
42	1255	1557	1608	1566	1738
43	1442	1795	1809	1777	1696
44	858	1171	1310	1341	1344
45	1292	1620	1683	1606	1668
46	1321	1788	1812	1868	1844
47	1442	2225	2088	2086	2005
48	1689	2622	2611	2195	2592
49	1131	2363	1977	1636	2023
50	984	2057	1952	1749	1960
51	1537	2708	2589	2039	2804
52	1657	2729	2698	2343	2682
53	1093	1778	1740	1355	1499

The table is given in full. The figures quoted have been checked and corrected, and are intended to replace all those previously published.

TABLE 13

1952 WHEAT TRIALS AT SADDLEWORTH.

Variety	Mean yield, bus./acre
Gabo × 3 Dirk (726)	38.6
Quadrat	38.5
Dirk 48	37.3
Insignia 49	37.3
Dirk 51	35.5
Sabre	33.9
Kendee	33.4
Warigo	31.2
Panther	29.7

Difference between two means of 1.6 bus./acre is significant at the 5 per cent. level of probability.

TABLE 14

COMPARATIVE CROP TRIALS, WAITE INSTITUTE, 1952-53.

Crop	Variety	Mean yield	Bushels/acre
		1952	1953
Wheat	Seewari	66.9 ±3.57	34.3 ±5.57
Linseed	Walsh	3.3	3.6
	Punjab 5	21.3 } ±0.53	13.7 } ±0.77
Safflower	47-53	38.0	33.3
	23	45.2 } ±1.66	39.4 } ±1.85
	48-89	50.1 ±1.27	39.5
Significant differences:			
Linseed, 0.1% probability		6.4	7.5
Safflower, 5% probability		6.5	—
Design		5 randomized blocks	6 randomized blocks
Plot size		1/41.9 cres	1/41.9 acres

- NOTE: (i) Standard errors are given as an indication of the variability of different crops under the same experimental conditions. They are valid for comparisons between means with the same standard error, but not for comparisons between means with different standard errors.
- (ii) In 1952 germination and emergence of safflower were affected by waterlogging of the seedbed, resulting in large empty patches on all plots. Variety 48-89 was particularly affected and had to be regarded as a total loss. All plots of this variety were therefore ploughed in and re-sown 5 weeks later, giving a cover of 98%, while the remaining two varieties achieved 74% and 70%, respectively. The mean yield of 48-89 is therefore not strictly comparable with the yields of 47-53 and 23. It is possible, however, that had conditions at planting been nearer the optimum, the yields of varieties 47-53 and 23 would have been rather higher. The stands of wheat or linseed did not appear to have been affected by waterlogging.

TABLE 15

LINSEED VARIETIES AND SELECTION TRIALS, WAITE INSTITUTE, 1950-53.

(gm. per row 12'×14".)				
<i>I. Varieties</i>	1950 (±6.5)	1951 (±5.8)	1952 (±7.7)	1953 (±11.0)
Punjab 5	182	96	198	182
" 20	172	87	194	161
" 23	161	66	199	77
Walsh	142	58	214	86
3046B	147	64	202	106
Sheyenne	150	78	183	86
Least significant differences:				
5%	19	18	—	33
1%	27	24	—	46
0.1%	—	—	—	63
<i>II. Selections</i>		(±4.3)	(±10.3)	(±10.7)
27		86	184	163
30		69	158	116
58		74	192	116
65		69	181	138
66		72	177	123
69		86	186	125
70		73	176	112
71		77	190	94
76		68	178	96
89		77	211	107
92		81	219	168
98		69	197	107
Walsh		58	199	94
Least significant differences:				
5%		12	30	31
1%		17	—	41
0.1%		—	—	54

Design: Four randomized blocks.

Plot size: 12'×14" single rows.

Commonwealth Scientific and Industrial Research Organization

*Staff with Headquarters at the Waite Agricultural Research Institute
(as at 31st December, 1953):*

DIVISION OF SOILS:

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Technical Secretary: A. L. C. Davidson, Ph.D. (Agric. Chem.) (London).

Clerical Staff: F. W. Blanksby. T. C. Baker.

Soil Physics Section:

Senior Principal Research Officer: T. J. Marshall, M.Ag.Sc., Ph.D.

Senior Research Officer: G. D. Aitchison, B.E.

Research Officers: K. Norrish, M.Sc., Ph.D., J. P. Quirk, B.Sc. (Agr.) Ph.D.,
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Laboratory Craftsmen: F. R. Pedler, K. J. Barrow.

Soil Chemistry Section:

Senior Research Chemist: C. S. Piper, D.Sc. (part time).

Principal Research Officer: A. C. Oertel (spectrography), M.Sc.

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Senior Research Officers: K. H. Northcote, B.Ag.Sc., G. Blackburn,
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Mulcahy, B.Sc. (Forestry), Ir. C. J. DeMooy.

Sectional Draughtsman: P. D. Hooper.

Draughtsmen: M. C. Coulls, M. J. Spooner.

Note: There are five Regional Centres—Brisbane, Hobart, Perth, Canberra
and Deniliquin—permanently staffed with research officers of the Soil
Survey, Soil Chemistry and Soil Physics Sections.

Soil Microbiology Section:

Principal Research Officer: R. J. Swaby, M.Sc., M.Ag.Sc., Ph.D.

Research Officer: J. R. Harris, M.Sc.

Technical Assistants: Bayes Lloyd, Margaret Altman.

C.S.I.R.O. Officers who have left for other appointments since 1st January, 1952:

W. H. Litchfield, J. Loveday (transferred to other Regional Centres).

Commonwealth Scientific and Industrial Research Organization

Division of Soils

1. INTRODUCTION.

The Division of Soils of the Commonwealth Scientific and Industrial Research Organization has its headquarters at the Waite Agricultural Research Institute, Adelaide, and the relationship has continued as a linked association with mutual advantage. The central organization of the Division has continued at an even level and its regional establishments throughout Australia have developed more maturely, with active laboratories associated with the survey work. New laboratories specifically for the Division are being built at Canberra and Perth.

Certain developments have occurred in the lines of work. The Pedology Section has moved more towards broad-scale mapping as opposed to the earlier detailed type and attempts are being made to assemble material for a new soil map of Australia in large regional units corresponding to the international map sheets. The wider mapping has become more practicable since New South Wales and Queensland inaugurated State soil survey units for domestic work.

In the laboratory, soil mineralogy on both the clay mineral and petrological sides has steadily developed as a line of investigation. Soil microbiology is moving into broader fields with the study of rhizosphere relationships of plants and micro-organisms and the examination of the soil organic matter fraction.

Five officers of the Division have been overseas for varying periods in Europe, America and the Philippines. Two officers on C.S.I.R.O. senior studentships have returned from Britain and two others are at present abroad in England and Sweden.

Attention may be drawn to the new series of publications being issued by C.S.I.R.O. specifically to deal with major papers on soils. These are called Soil Publications and three have so far been issued. The Division otherwise puts out a Soils and Land Use Series dealing with surveyed areas in a simpler less-technical form and covering land use problems. Divisional Reports and Technical Memoranda are issued on a restricted list.

2. SOIL SURVEY AND PEDOLOGY.

OPERATIONS IN SOUTH AUSTRALIA.

The major surveys have been in the Upper South-East, the Barossa district and the Murray Valley. Work continued to completion on the mapping of the 600 square miles of country between Keith and the Victorian border and on the Hundreds of Richards and Coombe in the Tintinara district. The survey of the Hundreds of Tatiara and Wirrega was begun in 1953. This is an older established area and about one-third forms the westward extension of the Vic-

torian Wimmera. In all this Upper South-East Region there are continually recurring fertility problems associated with trace elements and phosphorus and possibly potassium. These surveys, now totalling 1,600 square miles in a continuous block will provide an excellent foundation for experimental work and the application of results.

An area of 25,000 acres in the Hundreds of Woolumbool and Lochaber, west of Naracoorte, was examined in reconnaissance as a potential developmental project. The soils are generally of low fertility and some have significant problems in high groundwater, both with and without saline influences, and in erosion if the coarse textured ridge soils are not protected during dry summer months.

Arising from the survey in the Tintinara District, an experimental site was selected for the determination of soil salinity changes over an annual cycle. This is being tied in with the fluctuations of and salinity of the groundwater which is close to the surface for part of the year and never falls to deep levels. The monthly observations made with portable field sets are continuing with confirmatory laboratory analyses.

The Barossa District survey was continued and a further 15,000 acres covered in the vicinity of Seppeltsfield and Tanunda. With the finding of certain new soil formations not previously described in the earlier work, the complexity and potential problems, particularly viticultural, of the district become emphasized. The Barossa area represents a most interesting unit pedologically and from the land utilization aspect, including in some parts soil conservation problems.

Further work in the Murray Valley has added to existing irrigation schemes and explored the possibilities of others. Three units were surveyed. An extension of 1,000 acres has been added to the existing design of Loxton Irrigation Area following a survey in close detail with land use correlation of about 2,000 acres of adjacent land. The horticultural planting design was worked out on the basis of the recommendations and maps supplied by the Division. An area between Loxton and Renmark was examined as a potential irrigation development. This unit of 17,000 acres was surveyed partly (7,000 acres) in detail and partly in reconnaissance. The soils are comparable with those at Loxton in type and quality. A portion amounting to 5,000 acres was selected as quite suitable for close settlement under vines, citrus, stone and other fruits. An additional 1,500–2,000 acres picked up in reconnaissance could probably be usefully added if desired. This is the most promising known area of any size available on the Murray River in South Australia within recognized pumping lifts. A third unit of about 10,000 acres was surveyed in reconnaissance at Murtho above Renmark. It has some suitable soils but unfortunately the pumping lift to secure a reasonable block for development is 180 ft. which is thought too high for economic working. A great deal of land in the Murray Valley is deceptively shallow to stone and limestone rubble, and surveys in some detail are essential to determine the suitability for horticulture, and especially for some types of planting such as citrus and stone fruits. The question of spray or furrow irrigation recommendation has also to be answered on the basis of the soil survey and the physical characteristics of the types defined.

A close survey of the soils on the Martindale Estate, Mintaro, has been made at the request of the Waite Institute. The soils form an interesting group

showing the influence of topography, parent material and drainage on development of the soil profile and the inter-relationship of various members in the red brown earth and brown heavy textured soil groups. The survey with its full report and soil map should provide a good basis for future experimental work of the Waite Institute.

A detailed survey was made of the 10,000 acres of Campbell Park Estate south of Narrung which had been taken over by the State Land Development Executive for closer settlement. The work showed the subdivision into 12 soil types grouped into three sets according to water tables, salinity and relief. The types were correlated with potential land use with a regard to possible dairying settlement. Supplementary irrigation was considered by spray systems, as well as suspected mineral deficiencies and erodibility.

In the Adelaide Hills a series of spot surveys of typical units at Uraidla, Mount Barker, Inglewood and Mount Pleasant were conducted as a background to broad scale association mapping of the Adelaide 1-mile military sheet. This hills area is developing agriculturally and the survey provides data for advisory work and the definition of problems. The work is continuing.

In Adelaide suburban areas a number of estates have been examined as to soil types and building qualities on behalf of Commonwealth and State Housing Authorities. This links with the soil mechanics work outlined below.

OTHER PARTS OF AUSTRALIA.

Surveys in all States and the Northern Territory have been carried out during 1952-53. No major work has been done in Victoria but some large-scale surveys have been carried on in New South Wales, Queensland, Tasmania and Western Australia mainly as soil association mapping, but in all regions with some detailed work. In North Australia the Ord-Victoria region in the west and the Flinders-Gilbert region in the east have been worked on by the Divisional pedologist seconded to the C.S.I.R.O. Land Research and Regional Survey Section.

3. SOIL CHEMISTRY.

The work of the Section during 1952 and 1953 has covered a number of different fields including pedogenesis, physico-chemical studies of clay, availability of micronutrients and spectrochemistry. As usual, all type samples collected by the Soil Survey Section have been examined and it has been possible to give more detailed chemical assistance to some of the pedologists' problems.

TERRA ROSSA AND RENDZINA SOILS.

Laboratory investigations have been continued on these two groups of soils which occur in South Australia under the same climatic regime and frequently adjacent to one another on apparently similar calcareous parent material. The problem has been to determine why the pedogenic conditions give rise to red soils on one hand and black soils on the other.

Nineteen representative profiles of these soil groups have been examined chemically and, in collaboration with the Soil Mineralogy Section, mineralogically. It has been found that although the chemical properties of these two groups of soils are very similar their colour, which is their dominant morphological difference, is directly related to the ratio of the free ferric oxide associated with the clay fraction to the total organic matter. It was found con-

venient to use total nitrogen as a measure of soil organic matter. Black soils had a ratio of free ferric oxide to nitrogen of less than 10 while red soils had a ratio greater than 10. However, the degree of redness did not always correspond to progressive increases in the ratio. The mineralogical examination indicated that the anomalies could be attributed to other iron-bearing minerals, such as chlorite, present in the clay fraction. Apart from accounting for the difference in colour the chemical examination of these soils did not reveal any evidence bearing on their genesis. The mineralogical examination has enabled a theory of their genesis to be proposed.

THE AVAILABILITY OF MANGANESE IN SOILS.

A study of the behaviour of soils to different extracting reagents capable of forming complex anions with divalent and trivalent manganese has been continued. By this means more information is being obtained on the chemical forms of manganese and other heavy metals in the soil. Some of these extractants are proving suitable for measuring the efficacy of various soil treatments in increasing the level of reduced manganese in soils. They are also being used to study the oxidation of divalent manganese added to soils. In a pot experiment the uptake of manganese by oats from different compounds of manganese, when added to a highly deficient soil, has been determined. Tests have shown that divalent manganese added to this soil is rapidly oxidized.

ION EXCHANGE STUDIES.

Work on the ion exchange-pH relationships of soils containing clay minerals representative of the three main groups (montmorillonite, illite and kaolinite) has now been completed and written up for publication. Samples of soils saturated with one of the cations, sodium, potassium, calcium or magnesium, were brought to equilibrium with various amounts of the cation hydroxide or hydrochloric acid and the systems dialyzed under carbon-dioxide-free conditions. The curves connecting the amounts of exchangeable cations remaining on the clay at equilibrium with the pH of the suspension showed a common shape in the acid portion of the pH range except in the case of the kaolinitic soils. These showed the highest buffer capacity per exchange position. The pH relationships with sodium as the metal cation were characteristic for the three mineral types and could be used to differentiate them. Sodium was found to be easily hydrolyzed in soils containing illite giving relatively high pH values for low sodium contents.

Measurements of pH with the glass electrode successively in the dialysate and suspension indicated that equilibrium between the soil and the liquid phase was not readily attained under alkaline conditions. This lack of equilibrium is thought to be associated with the hydroxyl ion. It may lead to significant errors in the determination of the pH of alkaline soils.

The "suspension effect" has been measured by placing calomel electrodes in the suspension and in the dialysate. The monovalent cations sodium and potassium gave positive potentials with respect to the calomel electrode in the dialysate as negative, with the sole exception of the kaolinitic soils below pH 6. Calcium and magnesium-saturated soils always gave negative potentials. If the "suspension effect" represents the average potential between the Gouy double layer and the outside solution, it could then be shown that it was a function of the inverse of the square root of the concentration of the ions in the dialysate.

THE DETERMINATION OF pH IN SOILS.

In the routine determination of the pH of soils by the technique used in these laboratories, the errors due to the "suspension effect" were found to be relatively small. Errors due to lack of equilibrium between the soil and the aqueous phase occurred only at pH values greater than 5, but with some sedimentary alkaline suspensions the lack of equilibrium could give drifts as much as 1 pH unit. Other errors involved in the routine determination have been examined. Replicate determinations made consecutively upon the same day were found to have smaller errors than those made on different days. There were also small but significant differences between the errors in a group of eight observers. Field samples may show errors as high as 1.3 pH units, due to soil variations over small distances of the order of $\frac{1}{2}$ -chain.

As a result of this study the most suitable apparatus and technique for the routine determination of soil pH has been defined.

IMPROVEMENTS IN OTHER ANALYTICAL METHODS.

A simple method for the determination of exchangeable calcium and magnesium in calcareous soils has now been developed. A survey of the solubilities of calcium carbonate, dolomite and magnesite in a number of possible extracting solutions indicated that these alkaline earth carbonates had a solubility in normal ammonium chloride in 60 per cent. ethanol adjusted to pH 8.5 with ammonia equal to or somewhat less than that in air-free water. Comparative trials on a large number of soil types have shown that this new solution satisfactorily extracts exchangeable sodium, potassium, calcium and magnesium and that no correction is needed for the solubility of the alkaline earth carbonates. Sodium and potassium can be readily determined in the leachate by flame photometric methods and calcium and magnesium by titration with ethylene-diamine-tetra-acetate.

Further trials have been made with direct-reading flame photometers and the interactions of sodium, potassium, calcium and magnesium have been studied. Calcium had a marked effect on magnesium and further enhanced the difficulties associated with the determination of that element. A simplified flame photometer, with low temperature flame and optical filters, has also been examined and found useful for the determination of potassium and sodium. Calcium interferes with the determination of the latter element but suitable corrections can be applied.

A new colorimetric method for the determination of iron in plants, based on the photometric determination of ferric cupferronate in amyl acetate, has been developed and has been found very useful in the analysis of plants from pot experiments.

RAINWATER STUDIES.

Interest has continued in the collection and analysis of rainwater samples from different localities. The change in composition with distance from the coast is being examined. One of the greatest problems is the collection of the sample with the minimum of contamination. The use of ion exchange resins and collecting apparatus of polythene has been explored. The application of flame photometry and ethylene-diamine-tetra-acetate titrations has greatly simplified the analytical problems.

Another series of rain-water samples, collected weekly from certain forest areas, has been examined for the South Australian Department of Woods and Forests.

GENERAL SOIL ANALYSIS.

The laboratory examination of the type samples collected by the Soil Survey Section and other soil surveyors has formed an important part of the activities of this Section. Besides the routine descriptive analyses selected samples have been examined in regard to such special features as detailed particle size distribution, seasonal changes in salt content and the chemical analysis of the clay and other minerals in the soil. The greater part of the subsoil samples examined from the Barossa soil survey showed the presence of very uniform-sized grains of quartz. The surface etching of these grains was probably due to the alkaline conditions.

SPECTROCHEMICAL INVESTIGATIONS.

Much progress has been made with the assessment of the sources of errors in the quantitative spectrochemical techniques. Analytical precision in these laboratories has now reached a stage that no significant improvement can be expected from trial and error modifications. By analysis of the total error of a single determination the parts attributable to excitation of the sample and to measurement of line intensities have been separated. The determination of line intensity from line density was found to be subject to an error of about 2 per cent. and this could be further apportioned between the densitometer itself, the calibration curve for the conversion of line density to line intensity, and to variations in the photographic line image. This error of about 2 per cent., however, forms only a very small part of the total error of about 10 per cent. for a single determination. Thus the errors associated with the excitation of the samples must be reduced in order to effect any significant reduction in the overall error. In this connection factors such as lack of stability of the discharge, arc current, basic composition of the sample and level of concentration of the elements being determined have been investigated.

A series of lateritic soils from Western Australia has been examined spectrographically and the distribution of calcium and magnesium, copper, gallium, lead, manganese and molybdenum followed both throughout the soil profile and in the ferruginous concretions.

Copper, manganese, molybdenum and zinc have also been determined in a number of profiles representative of four major soil groups from South Australia. Mineral samples have been examined spectrographically for various Government departments and assistance has also been provided to other research workers by examining samples from mineralogical and plant nutrition studies.

4. SOIL PHYSICS, MECHANICS AND MINERALOGY

SOIL STRUCTURE.

Further work is being carried out on the effect of initial water content on the water-stability of soil aggregates. In general, the higher the water content of the soil before it is placed in water, the greater will be the stability. The relative effects on cultivated and virgin soils is being examined. At the same time an attempt is being made to evaluate the factors responsible for differences in stability.

In connection with a chemical and mineralogical study of soils of the terra rossa and rendzina groups, a study is being made of structure of these soils in relation to aeration and development of the soil profile.

A method has been developed for measuring the apparent density of aggregates down to 2 mm. in diameter with an accuracy of 2 per cent. by draining at a small tension after removing air and wetting with kerosene. Volume is determined by displacement in kerosene.

SURFACE AREA OF SOILS.

A study has been made of the application of the adsorption isotherm of Brunauer, Emmett and Teller to adsorption of water vapour by soil. Some preliminary results show that surface area of clays determined by this means may be considerably higher than when determined from nitrogen adsorption. These results may be important in extending the information available from particle-size analysis which does not normally extend into the range of the finest particles. Preliminary work with negative adsorption using (i) ethylene glycol and (ii) chloride in the presence of calcium chloride is proceeding.

SOIL PHYSICAL PROPERTIES AND ELECTROLYTE CONCENTRATION.

The effect of electrolyte concentration on the permeability and swelling of soils is being investigated. It is intended that the results of the permeability work will be used in relation to the maintenance of permeability of certain soils which have appreciable quantities of sodium on the exchange complex. For each degree of sodium saturation there is a particular level of electrolyte required in the irrigation water to maintain stable aggregation of the soil. If the level of electrolyte is too low, decreases in permeability are obtained due to dispersion. By adding a calcium salt such as gypsum to the irrigation water, the permeability of the soil is maintained while the sodium associated with the clay is replaced by calcium. When this process is complete it will not be necessary to add calcium salts to the irrigation water. The present work has added more precision to a reclamation process long known in irrigation practice.

The work previously described on the swelling of clay blocks has been extended to include a study of the effect of electrolyte concentration and exchangeable cation on the degree of swelling. So far it has been shown that the level of electrolyte results in only small differences in the degree of swelling of the calcium-saturated clay within the range likely to be encountered in the field. The work is being continued for a sodium-saturated clay.

In connection with work proceeding on liquid and vapour-flow through soils it is necessary to know if the moving concentration in the liquid is well evaluated by the ratio of total chloride to water content. It has been shown that on account of the compensating effects of negative adsorption and positive adsorption at the particular pH value of the soils errors involved in this assumption are small.

EROSION AND THE FORMATION OF SURFACE SEALS.

Laboratory and field measurements are continuing on the study of soil splash, and the formation and properties of surface seals under the impact of raindrops. Test plots for field work are all on the one soil type but have had different agricultural treatments. Treatment differences show up both in the amount of soil splashed and its particle-size distribution.

Damage to soil surfaces comparable with that experienced in the field is carried out in the laboratory with a rain simulator, the drop energy being varied by its distance of fall. With high energies more splash occurs on the well-aggregated stable soil due to the movement of relatively large aggregates, but on the unstable soil the splash consists of highly-dispersed particles and therefore damage is greater. On all soils the amount of splash from the surface reaches a constant value as the total energy dissipated at the soil surface is increased. Amount of splash depends also on the rate of wetting.

As might be expected seal formation occurs much more rapidly and to a greater extent on the unstable soils. The effect of seals on air-water-soil relationships is being investigated with laboratory and field-formed seals, and the makeup and properties of seals is also under study.

PERMEABILITY.

Results obtained from the movement of water and chlorides in columns of soil from which water is allowed to evaporate at one end, show that in isothermal conditions water-flow occurs as liquid in soils wetter than wilting percentage, with negligible vapour flow. The evaporating soil columns have given results relating the rate of flow of water to the tension gradient within the columns, from which some values of unsaturated permeability have been calculated for water content values down to the wilting percentage. Further development of this technique is in hand to improve the accuracy of the permeability values obtained, particularly at high water contents. With these data it will be possible to test a modified form of the Kozeny-Carman equation for flow of water through soil. This modification has been developed to meet unsaturated conditions. The application of this equation to saturated soils is being considered using a structural surface as distinct from a total surface area of the soil.

VAPOUR LOSSES FROM PRESSURE MEMBRANE APPARATUS.

The pressure membrane apparatus is standard equipment in the laboratory for the measurement of water content of soil in relation to soil water tension. Loss of vapour through the cellophane membrane of the pressure membrane apparatus would affect this measurement. The extent to which this can occur has been measured at a range of pressures and it is concluded that this type of loss is unimportant. However, losses occurring from other parts of the apparatus may be significant and it is suggested that at the commencement of each run the apparatus be brought up to pressure and then the gas cut off at the source. The loss of gas in the first day may then be used to check these leaks.

MEASUREMENT OF SOIL WATER STATUS IN THE FIELD.

The neutron method of measuring soil water content is being adapted for use in the field. It promises to be particularly useful in variable soils because it measures a volume of about 1 cubic foot of soil thus tending to average out the scatter obtained in individual soil samples of smaller size. Attention is also being given to the development of techniques to measure soil water status in arid conditions. An attempt is being made to assess quantitatively the accuracy to be expected from the gypsum block which is used extensively as a field unit.

SEASONAL CHANGES IN WATER CONTENT AND MOVEMENT OF CLAY SOILS.

Field studies of the seasonal change of water status of the soil profile are continuing in Adelaide. At the same time the vertical movements of the soil,

resulting from changes in water content, are being measured. Part of this work has been completed and two papers have been published on it. The maximum depth of the seasonal penetration of rain and the progress of drying in the soil profile have been determined for the Adelaide climate and typical soil environments. Water penetration of the order of 10 ft. has been noted in red brown earth soils by the late winter. Soil water changes and earth movements have been correlated. This work is providing information to assist in the design of house foundations appropriate to the clay soils of Adelaide.

The amount of water seasonally stored in the soil profile has been measured at a number of sites in Adelaide and found to be 8 to 9 inches in a normal red brown earth profile. This storage has been compared with the amount estimated from the annual sum of precipitation corrected for evaporative losses according to various formulae.

SWELLING OF CLAY SOILS.

Laboratory work on soils liable to extensive volume change is being undertaken. The change in volume accompanying changing water content and soil water tension has been measured on remoulded clay blocks. The water content-volume relation is unique but considerable hysteresis is evident in the soil water tension relation with water content (or volume), according to whether the final equilibrium water content is reached by drying or wetting the soil.

EXAMINATION OF SOILS FOR BUILDING PURPOSES.

The survey of the soils of Adelaide suburbs carried through in previous years has now been prepared for publication together with a discussion of their engineering properties. A generalized map of the soils and a description of their characteristics and behaviour is provided. Colour photographs of soil profiles will assist in their identification by the architect or builder concerned with selecting a type of foundation suited to a particular soil. This publication is being put out in conjunction with the Department of Mines, South Australia, which has assumed responsibility for an advisory service relating to soils and house foundations for private enquirers.

Following a request from the Architect-in-Chief's Department, South Australia, the soils of the Northfield Mental Hospital area were examined. A report has been made on soil strength and water content conditions as they affect the design of large extensions to the hospital where the soils are of a problem nature for foundation structures. Advice on the merit of sites for group housing has also been given to the War Service Homes Division.

GENERAL.

The necessity for a basic knowledge of soil physics in certain agronomic, engineering and climatological studies has brought a large number of enquiries for consultation and aid. During the year many groups in and out of the Organization have been helped with advice and measurements concerning soil physical properties.

CLAY MINERALOGY.

Work has continued on the X-ray spectrograph and experiments indicate that it is suitable for detecting elements of greater atomic number than potassium. Under favourable circumstances one part in 10,000 can be detected. A

Geiger counter is to be used for measuring the X-ray intensities and with this it is hoped that the sensitivity will be increased and that quantitative analyses can be made.

A comparative study of the mineralogy of the black soils and krasnozems which occur at Lismore, N.S.W., has been completed. These two soils are very different in the field and in their mineralogy, the red soils being mainly kaolin with free oxides while montmorillonite was dominant in the black soils. The mineral studies indicated that the two soils, which occur side by side on basalt, represent different stages in the one weathering process. This study is now being extended to krasnozems from other parts of Australia.

An investigation into the structure of cookeite was also undertaken. Cookeite has a chlorite structure but is unusual in containing no iron or magnesium. Aluminium with a little lithium occupies the octahedral positions.

5. SOIL MICROBIOLOGY.

Micronutrients and Microorganisms.

Bioassays of 15 rocks and 65 minerals were made for amounts of micronutrients available to *Aspergillus niger*. The order of release of trace elements was iron, molybdenum, manganese, copper and zinc least of all. Those minerals featuring these elements in their chemical formulae tended to be fairly good sources but some not suspected were found to provide nutrients in moderate amounts. A test was made of *Curvularia* as an indicator plant but in comparative studies it gave similar results to *Aspergillus*. Contact between hyphae and soil is not necessary, except in calcareous soils, for acquiring iron and manganese. A reducing agent or a non-toxic chelating agent assist both moulds to obtain the manganese and iron adsorbed on calcium carbonate. In attempts to bioassay soils for boron and cobalt no small organisms other than *Chlorella vulgaris* and *Lemna minor* showed deficiency symptoms for boron. None of the organisms tested proved satisfactory and the bioassays were abandoned.

Using a macrorespirometer developed in this laboratory, studies have been made of the effect of the absence of macro and micronutrients on microbial respiration. A selection of organic and inorganic nitrogenous manures were tested and classified into three groups depending on levels of availability of nitrogen.

- (1) Nitrates, ammonium salts, urea, asparagine, yeast extract, casein, peptone—good sources.
- (2) Fungal mycelium, yeast cells, red clover—fairly good sources.
- (3) Cereal straws, sawdust and humus—poor sources.

This order with soil microorganisms closely parallels that known for plants.

Using mineral and organic phosphatic fertilizers three classes also were distinguished in terms of availability.

- (1) Alkali-, super-, serpentine-, silico-, glycerophosphates and nucleic acid—readily available.
- (2) basic slag, ferric phosphate, dicalcium phosphate, defluorinated rock phosphate, aluminium phosphate, lecithin—fair suppliers of phosphorus.
- (3) Rock phosphate, phytates—poor suppliers of phosphate.

A number of phosphatic minerals containing calcium, iron or aluminium were bioassayed but none were good sources of phosphorus supply to microorganisms.

RHIZOBIUM—CLOVER STUDIES.

Some strains of *Rhizobium* applied to the seed coat in the manner of commercial inoculum are able to form effective associations with subterranean clover in pots of sterilized soil in the glasshouse, but under natural conditions in the field are unable to establish themselves in the face of competition of indigenous flora. In competition in the soil for sites for nodule formation on clover roots some prove more effective than others and this is attributed to a power of "incursion". Field tests have shown a failure to symbiose with subterranean clover, sometimes in the first year, sometimes for no more than one year, possibly due to an inability to persist through a hot summer in dry soil in the absence of a host plant.

Continued studies on virulence and incursion have been made with 40 strains of *Rhizobium trifolii*. The importance of the incursive properties of the organism has been emphasized and efficient fixers of nitrogen are not necessarily adapted to the soil environment as effectiveness and incursion are independent qualities. The search for appropriate strains is proceeding and tests designed for assessing their power in both capacities.

SOIL HUMUS.

Attempts have been made to fractionate humic acid into its component colloidal constituents by fractional precipitation, partition and adsorption chromatography and paper electrophoresis without success. Attempts to break the strong bonds between constituents have been made. The investigation has developed in an endeavour to isolate proteins and polysaccharides by electrophoresis. Mechanism of the test for proteins by bromphenol blue—mercuric chloride method was studied to improve its sensitivity. It was found that the affinity of certain anionic dyes depended on cationic groups on the proteins so that basic proteins stained more intensely than acidic proteins. Dyeing was enhanced by acidic and diminished by alkaline conditions. Aqueous solutions of dyes wetted the protein spots on paper poorly, resulting in patchy colours, but this was overcome by adding detergents or by using alcoholic solutions of the dyes. Various proteins, polysaccharides and dyes, when deliberately added to sodium humate and to humic acid were fairly easily separated by electrophoresis even after long periods of contact. The reasons why intact proteins and polysaccharides cannot be detected in humus are being further studied.

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Oenological Research

(Chairman of Committee: PROFESSOR J. A. PRESCOTT, C.B.E., D.Sc., F.R.S.)

Staff as at 31st December, 1953.

Senior Research Officer: J. C. M. FORNACHON, M.Sc., B.Ag.Sc.

Research Officer: B. C. RANKINE, B.Sc.

Assistant: MAUREEN T. WHITE.

Oenological research at the Waite Institute is conducted under a special committee of the C.S.I.R.O. representative of the wine industry and the scientific disciplines concerned. It is financed in equal parts by the Australian Wine Board and the Federal Treasury.

1. SHERRY INVESTIGATIONS.

The results of the investigations into the nature of the flor yeasts, the changes which they bring about in wines and the effects of various factors on their growth and metabolism, have been published in the form of a monograph.

Experimental work on the subject of flor sherry has been set aside for the present.

2. WINE YEASTS.

The laboratory examination of a large number of strains of wine yeasts from both local and overseas sources has been continued and certain strains have been selected on the basis of superior production of ethyl alcohol. This work has been extended to Winery trials using the selected yeasts in fresh grape juice in association with the normal flora of the grapes. The results obtained have been very encouraging in that the selected yeasts tend to produce more ethyl alcohol and conduct a more rapid and even fermentation. Certain strains have the ability to flocculate very rapidly after fermentation leaving the supernatant wine clear. This characteristic is considered important and further work on this aspect of the subject is in progress. The association of a number of pairs of wine yeasts has been examined experimentally with interesting findings. The final quantity of ethyl alcohol produced by a mixture of two yeasts in the one culture was found to correspond to that produced by either one or the other yeast in pure culture, but did not fall between them. From this it was inferred that the yeasts were antagonistic and competed with one another during fermentation. The proportions of the two yeasts present at inoculation decided which strain would dominate the fermentation. This finding is important industrially in the use of pure starter cultures of a selected yeast in winemaking, in the presence of other yeasts present in the grape juice.

3. MALO-LACTIC FERMENTATION.

It is known that the bacterial decomposition of malic acid to lactic acid and carbon dioxide is an important feature of the early stages of maturation of many of the high quality dry wines of Europe.

As a result of this so-called malo-lactic fermentation the acidity of the wine is decreased and its palatibility improved. This is particularly valuable in cool districts where the grapes often contain much malic acid when harvested and many of the wines would be too sour if the acidity were not decreased in some way. Although bacterial decomposition of malic acid has been noticed occasionally in Australian wines, little is known about the frequency or importance of this change under our conditions. It has commonly been assumed that, because of the warm climate of most of our viticultural areas, our young wines contain insufficient malic acid to support a vigorous malo-lactic fermentation or to render such a fermentation particularly desirable.

Investigations commenced during the 1953 vintage season have shown that malic acid is much more plentiful in our young wines than was previously supposed. Even the warmest districts produce some wines which contain more malic acid than tartaric acid. Of 130 young dry wines of the 1953 vintage which were examined, 65 underwent malo-lactic fermentation. The pH value and the SO_2 content of these wines appeared to be two of the most important factors affecting bacterial activity, for the incidence of the fermentation was highest in the wines with high pH values and low doses of SO_2 .

Twenty-six strains of heterofermentative lactobacilli capable of decomposing malic acid in wine, have been isolated from wines and these are being studied in the laboratory.

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